THE NICKEL BULLETIN

Monthly Abstracts of Recent Literature

OCTOBER-NOVEMBER

1961 Volume 34 No. 10-11

THE INTERNATIONAL NICKEL COMPANY (MOND) LIMITED

THAMES HOUSE MILLBANK LONDON SW1

Telephone: VICtoria 3888

OCTOBER–NOVEMBER 1961 VOLUME 34 No. 10–11

INDEX

Nickel Page

Precipitation Process for Recovery of Nickel and Cobalt from Lateritic Ores 238
Roasting Processes Employed by INCO 238
Melting of Malleable Nickel and Nickel-base Alloys 239
Flade Potential of Nickel 240
State of Advancement of Battery Technology 240
Comparative Review of Different Types of Storage Battery 240
Nickel-Cadmium Cells with a High Energy/Weight Ratio 240

Electrodeposition and Other Coating Methods

Corrosion-Resistance of Copper/Nickel/Chromium Coatings on Steel 241
Decorative Nickel/Chromium Plating in the U.S.A. 242
Corrosion Behaviour and Levelling Performance of Bright-Nickel and Double-Layer Nickel Deposits 242
Crack-Free and Microcracked Chromium Overcoatings 243
Significance of Thick Chromium Coatings 243
Corrosion Protection of Various Electrodeposited Coating Systems 243
Copper as an Intermediate Layer in Electrodeposited Coatings 244
The Copper Undercoating in Copper/Nickel/Chromium Coatings 244
Improvements in Nickel Plating of Zinc-base Die Castings 245
Study of Extremely Thin Nickel Coatings 245
Levelling in Bright-Nickel-Plating Solutions 245
Influence of Brightening Agents on the Characteristics of Electroless Nickel-Plating Solutions 246
Influence of Thiourea on the Deposition Reactions of Iron and Nickel 246
Deposition of Nickel From a Liquid-Metal Solution 246
Electrodeposition of Nickel-Iron Alloys from the Pyrophosphate Solution 247
Thermoelectric Gauge for Determining the Thickness of Nickel Coatings 247
Determination of Zinc in Nickel Electrolytes 248

Non-Ferrous Alloys

Report of the Royal Mint: Nickel-containing Coinage 248
Intermediate Temperature Ductility Minimum in Metals 248
Gadolinium-Nickel System 249
Titanium-Nickel System between Ti_2Ni and TiNi 249
Ternary Alloys of Nickel and Nitrogen with Magnesium, Aluminium, Zinc and Cadmium 249
Structure and Properties of a Copper-Nickel-Silicon Age-Hardenable Alloy 249

Nickel-Iron Alloys

Iron-Nickel-Gold Ternary System 250
Sigma Phase in the Iron-Nickel-Silicon System 250
Influence of Heat-Treatment on the Permeability of Nickel-Iron Alloys 251
Solubility of Nitrogen in Iron-Nickel Alloys at 1000°C. 251

Cast Iron

Magnetic Properties of Nickel-containing S.G. Iron 251

Constructional Steels

Cast Steel with Special Magnetic Properties 252
Glassing Characteristics of Nickel-containing Low-Alloy Steels 253

Constructional Steels (*contd.*) Page

Formula for Prediction of Susceptibility to Heat-Affected-Zone Cracking in Steels 253
Influence of Welding Variables on the Yield Strength of Low-Alloy-Steel Weld Metal 254
Welding of '300M' Steel Sheet for Missile Motor Cases 254
Properties of 9 per cent. Nickel Steel in Heavy Sections 255

Heat- and Corrosion-Resisting Materials

Kinetics of Oxygen Adsorption on Nickel and an Iron-Nickel-Chromium Alloy 255
Influence of Silicon Additions on Oxide Films Formed on Nickel-containing Heat-Resisting Materials 256
Properties of Dispersion-Strengthened Materials 256
Condensing Heat-Transfer Rates of Nickel-containing Condenser-Tube Materials 256
Notch Sensitivity in 'A-286' Steel 257
Tensile Properties of '17-7 P.H.' Under Rapid-Heating Conditions 257
Explosive Forming of Nickel-containing Materials 258
Forgings in High-Temperature Alloys 258
Surface Coatings for Protection of High-Temperature Alloys During Heat-Treatment 259
Metallizing of Machinery and Moulds Used in the Glass Industry 259
Spectroscopic Standard Samples for Nickel-containing High-Temperature Alloys 260
Minimum Temperature Limits of Oil-Ash Corrosion 260
Resistance of 'Hastelloy B' to Corrosion by Rubidium at High Temperatures 260
Intercrystalline Penetration of a Nickel Alloy by Liquid Bismuth 261
Fundamental Behaviour of Passive Alloys 261
Anodic Polarization of Stainless Steel in Chloride Solutions 261
Study of Pitting Corrosion in Austenitic Stainless Steels 262
„ „ „ „ „ Stainless Steels by Turnbull's Colour Reaction 262
Influence of Ageing Temperature on Stress-Corrosion Cracking of '17-4 P.H.' 262
Susceptibility of 'AM-350' to Stress Corrosion in the Notched Condition 263
Symposium on Handling of Acid Slurries 263-5
Heat Treating Stainless-Steel Strip, Sheet and Plate 265
Determination of Ferrite Content in Austenitic Steels 265
Magnetic Technique for Estimation of Ferrite in Stainless-Steel Welds 266
Flash Welding of Nickel-base High-Temperature Alloys 266
Welding of 'Inconel' for Nuclear-Reactor Applications 266
Fabrication and Properties of Welded 'Inconel' Pipe 267
Welded Nickel-Alloy Tubular-Bladed Turbine Wheel 267
Welding and Heat-Treatment Procedures for 'P.H. 15-7 Mo' Sheet 267
Welding Chromium-Molybdenum Steel to 17-12-Mo Stainless Steel for High-Temperature Service 268
Development of Ductile Nickel-base Brazing Alloys 268
Wide-Gap Brazing of Components for High-Temperature Service 269
Wetting Tests on 'Inconel' and 'Inconel X' with Silver Brazing Alloys Containing Platinum Metals 270

Analysis 271

Patents 271-9

Corrigenda 279

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

NICKEL

Precipitation Process for Recovery of Nickel and Cobalt from Lateritic Ores

T. K. ROY: 'Preparing Nickel and Cobalt Concentrates.'

Industrial and Engineering Chemistry, 1961, vol. 53, July, pp. 559-66.

The precipitation process discussed by the author was incorporated, after extensive laboratory and pilot-plant investigations, as a key stage in the treatment of nickeliferous iron oxide in the nickel-concentration plant built by Freeport Sulphur Company at Moa Bay, Cuba. Full details are given of the reaction conditions and the batch precipitation tests which formed the basis for the subsequent design of a multi-stage continuous reactor.

The lateritic ore (containing 1·3-1·4 per cent. nickel and 0·12-0·14 per cent. cobalt) is treated with dilute sulphuric acid at 450°-500°F. (230°-260°C.) in steam-agitated multi-stage towers. The subsequent precipitation treatment, the subject of the present paper, is based on the finding that, although cobalt and nickel are not precipitated if hydrogen-sulphide gas is bubbled through a solution of their salts containing a free mineral acid, addition of a very small amount of nickel or iron powder to the acidic sulphate solution (pH 1·5) catalyzes their precipitation at atmospheric pressure. At higher temperatures and higher pressures of hydrogen sulphide, the precipitation reaction is so rapid that addition of metal powder is not necessary to catalyze it. The reaction is selective and virtually complete.

The sulphide-precipitation reactors at the Moa Bay plant began production of nickel-cobalt concentrate for shipment to the Port Nickel Refinery, Louisiana, early in 1960. The precipitation plant was designed to enable about 2,500 gal./minute of raw acid leach liquor to be treated with hydrogen sulphide, producing 125 tons of concentrate (containing 56 per cent. nickel and 5 per cent. cobalt) per day. At Port Nickel the concentrate is oxidized with compressed air to form a concentrated sulphate solution. Nickel and cobalt are then separated by selective hydrogen reduction. Due to political changes in Cuba, both plants were, however, shut down soon after they went on stream.

Roasting Processes Employed by INCO

R. R. SADDINGTON, W. CURLOOK and H. J. ROORDA: 'Roasting Practices at International Nickel.'

Paper presented at the *Annual Meeting of the Canadian Inst. Mining and Metallurgy*, Mar. 1961; 24 pp.+ figures.

The copper-nickel sulphide ore deposits of The International Nickel Company of Canada, Limited, contain the minerals pyrrhotite, pentlandite and chalcopyrite. In the extraction of the nickel, copper and iron, much of the processing involves oxidation of the metals as well as sulphur, and roasting plays a predominant rôle at several stages in the operations which prepare the constituent metals for refining. INCO's roasting experience dates back to the time when lump ore was partially roasted in heaps, and has since been continually extended, with the introduction of single-hearth roasters, sinter machines, multi-hearth roasters, flash roasters and, more recently, fluid-bed roasters. Although hearth roasters are giving way to fluid-bed roasters, they still offer advantages in some applications, such as in counter-current or multi-stage processing. The sinter machine is losing ground in sulphide roasting, but is gaining importance in the treating of iron-oxide ores. Flash roasting is still retained in special fields. In the treatment of sulphide ores, these older techniques are, however, in most cases being replaced by fluid-bed reactors.

This review of the roasting practices employed by INCO is in four sections, covering, respectively: partial roasting of mill nickel concentrates in multi-hearth roasters; partial fluid-bed roasting of nickel concentrates; roasting of pyrrhotite for iron-ore recovery (fluid-bed roasting of pyrrhotite, kiln reduction); fluid-bed roasting of nickel sulphide. Discussion of the techniques, equipment and reactions involved is supplemented by flow sheets, process data and illustrations.

Melting of Malleable Nickel and Nickel-base Alloys

C. G. BIEBER and R. F. DECKER: 'The Melting of Malleable Nickel and Nickel Alloys.'

Trans. Metallurgical Soc., A.I.M.E., 1961, vol. 221, June, pp. 629–36.

Introducing their subject, the authors allude to the fact that the first malleable nickel was produced by Fleitman in about 1870 by adding manganese and magnesium to the molten metal to counteract the harmful effects of sulphur. The practice of treating nickel with manganese and magnesium came to be called 'deoxidation', and was employed, without appreciable modification, for the commercial production of wrought nickel and high-nickel alloys (in the present paper 'high-nickel' alloys are regarded as those containing 50 per cent. or more nickel) until about 1930, even though results were never entirely satisfactory. In 1930, an extensive study was made of the effects of minor constituents on malleability and metallurgical quality. The results, a few of which have been published previously, are presented by the authors in this paper, together with other pertinent data.

Systematic additions (0·5 per cent. or less) of each of most of the elements of the periodic table were made to commercially pure nickel, and it was established that some minor constituents, other than manganese and magnesium, had a considerable influence on malleability. Malleability, evaluated in terms of reduction-in-area in tensile tests, was found to depend roughly on temperature. Four temperature zones were of interest in this respect: the cold malleable zone up to about 1000°F. (540°C.) ; the red short zone from roughly 1000° to 1500°F. (540°–815°C.); the hot malleable zone in the region of 2000°F. (1095°C.); and the incipient melting zone. Most of the malleability problems were associated with the red short zone, to which the authors' discussion mainly relates.

In the paper the effects of minor constituents are related to atomic diameter, valence and position in the periodic table. The basic methods of removing or neutralizing deleterious elements from nickel and nickel-alloy melts are then reviewed, and finally the authors give details of practical methods of melting and deoxidation, which (developed by combining sound metallurgical practices with the theoretical principles established in the research programme described) are recommended for the production of nickel-base alloys exhibiting improved malleability and a minimum of seams, inclusions and other metallurgical defects. The procedures recommended are quoted below.

Melting of Nickel

Since electrolytic nickel has been refined by the method of production, only melting, degassing, and the addition of small amounts of minor constituents precede casting into ingots. Charges consisting of electrolytic nickel, clean nickel mill scrap and about 1 per cent. of low-sulfur charcoal ma- be melted in gas-heated hearth furnaces. These furnaces may be lined with bricks consisting of about 55 per cent. silica and 45 per cent. alumina. No slag need be added intentionally, but some incidental slag is always formed by fusion of the refractories.

The nickel heats should be melted down with about 0·25 per cent. carbon. When the temperature of the bath has reached 2850°F. (1565°C.), the carbon content should be reduced to about 0·05 to 0·10 per cent. by the addition of nickel oxide. This gives the CO boil. After the carbon content has been adjusted to the desired level, approximately 0·3 per cent. manganese should be added and the metal tapped into bottom-pour ladles. Small amounts of titanium, boron, and magnesium should be added. The metal should be teemed at about 2800°F. (1540°C.) into cast-iron molds of appropriate size and design. This temperature and other pouring temperatures mentioned later are as measured with an optical pyrometer set for 0·4 emissivity. The readings are taken on the stream of metal being teemed from the ladle into the mold.

The practice just described will produce commercially pure nickel suitable for most applications. However, certain electronic applications require that the nickel strip be treated only with manganese and magnesium, since the other 'malleabilizing' and gas-fixing elements are believed to be harmful to the end products.

One special technique which can be used to produce high-purity nickel should be mentioned here. The melting stock is high-purity carbonyl-nickel powder, with the principal impurities being carbon and oxygen. The steps are:

(1) Melt in air or under argon to promote the CO boil. Oxidizing conditions remove carbon to a level around 0·001 per cent.

(2) Remove oxygen by magnesium deoxidation and cast.

(3) After cropping the top of the ingot, which contains most of the MgO, vacuum melt the ingot. This reduces residual magnesium to less than 0·01 per cent.

Nickel of 99·99 per cent. purity can be produced by this technique, providing that extreme care is taken in preventing contamination (from crucibles, etc.).

Melting of Nickel-Chromium-base Alloys

These alloys are preferably melted in a coreless induction furnace. A lining which consists of 40 per cent. alumina and 60 per cent. magnesia gives excellent results.

The charges should consist of electrolytic nickel, low-carbon ferrochromium and clean mill scrap of the same alloy. The scrap and electrolytic nickel should be melted first, followed by the ferrochromium. No slag need be added to the material in the furnace. When the temperature of the bath has reached about 2950°F. (1620°C.), small amounts of aluminium, titanium, boron and magnesium should be added. The metal is then tapped into ladles (preferably bottom-pour) and teemed at 2900°F. (1595°C.) into cast-iron molds, from which the ingots are then stripped and processed. Nickel-chromium-base alloys may also be melted in electric-arc furnaces with basic magnesite 'bottoms'. This permits an oxygen lance to be used to reduce carbon picked up from oily or high-carbon scrap. After the CO boil, the temperature of the bath should be lowered by adding cold metal, and oxides in the slag should be reduced by aluminium chips or ferrosilicon. Then small amounts of aluminium, titanium, boron, and magnesium should be added. The arc-furnace melts should then be tapped in the same manner as those from induction furnaces.

The aluminium plus titanium age-hardenable nickel-chromium alloys operate in service in the red short zone. The addition of boron and zirconium is particularly beneficial to ductility and rupture strength for this type of application.

Melting of High-Nickel Nickel-Copper Alloys

These alloys are preferably melted in electric-arc furnaces on basic magnesite 'bottoms'. The charges should consist of clean mill scrap of the alloy and electrolytic nickel and copper. They should be melted with enough carbon to finish with about 0·25 per cent. of the element, and refined under a reducing slag consisting of approximately equal parts of lime and fluorspar mixed with a small amount of carbon in the form of ground electrode dust. After the refining period is completed, the first slag should be removed from the furnace and the carbon content lowered by the addition of nickel oxide or the use of an oxygen lance. This results in a CO boil, which is to be continued until the carbon content of the melt has reached about 0·15 per cent. A second slag of lime and fluorspar should then be placed on the melt and the temperature adjusted to about 2750°F. (1510°C.). The oxides in the slag should then be reduced with carbon electrode dust, and additions should be made of small amounts of silicon, phosphorus, titanium, zirconium, and magnesium. The heats should be tapped at about 2700°F. (1485°C.), into cast-iron ingot molds of suitable size.

Deposition of Nickel from a Liquid-Metal Solution

See abstract on p. 246.

Flade Potential of Nickel

L. F. TRUEB, G. TRÜMPLER and N. IBL: 'The Flade Potential of Nickel.'

Helvetica Chimica Acta, 1961, vol. 44, No. 4, June 15, pp. 960–8.

The Flade potential of nickel in sulphuric acid was studied by determination of potential–decay curves as a function of time in the pH range 0–2.

Depending on the time during which the anode was held in the passive state, the decay was found to proceed through 0–3 plateaux. The position of the plateaux could be fully explained neither in terms of the adsorption theory, nor on the basis of the oxide theory which postulates the formation of complex oxide layers. It is suggested that the initiation of passivation is probably due to chemisorbed oxygen, which, after some time, is transformed into oxide with a non-stoichiometric and highly defective structure, with a lack of oxygen at the metal/oxide phase boundary and an excess of oxygen at the oxide/electrolyte interface.

Kinetics of Oxygen Adsorption on Nickel

See abstract on p. 255.

Intercrystalline Penetration of Nickel

See abstract on p. 261.

Structural Study of Ternary Alloys of Nickel and Nitrogen with Magnesium, Aluminium, Zinc and Cadmium

See abstract on p. 249.

State of Advancement of Battery Technology

J. J. LANDER: 'The General State of Advancement of Battery Technology.'

Soc. Automotive Engineers, 1961, *Preprint* 269*E*; 6 pp.

The purpose of the paper is 'to show how far electrochemistry and battery technology have progressed in the utilization of the energy of materials'.

In the first section of the paper energy-withdrawal rate, temperature and battery size are discussed in terms of their effects on the performance of different types of battery. Theoretical and practical values of energy yield tabulated for various types of fuel cell and secondary and primary battery lead the author to conclude that, although no startling advances have been made in the utilization of higher-energy materials in batteries, the energy capability of both primary and secondary batteries has been more than doubled in the last three decades, apart from the many 'fringe benefits' which have been achieved.

In the second, and final, section of the paper, the author examines the performance of specific battery systems, briefly discusses the major factors obstructing improvements in the energy yield, and attempts a qualitative estimation of the degree of improvement to be expected. In this connexion, he considers: secondary batteries (of lead/acid, nickel/cadmium, silver-oxide/cadmium and silver-oxide/zinc type); primary batteries of non-reserve and reserve (silver-oxide/zinc, fused-salt-electrolyte) type; and sodium/chlorine, hydrogen/oxygen, and direct-burning hydrocarbon/air fuel cells.

Comparative Review of Different Types of Storage Battery

C. G. GRIMES and W. S. HERBERT: 'The Choice of Battery Systems.'

Soc. Automotive Engineers, 1961, *Preprint* 269*D*; 6 pp.

In considering the type of storage battery which will best fulfil the requirements of a specific application, a compromise will usually have to be made between such factors as availability, weight, volume, rechargeability, cycle life, stand life, cost and maintenance. Six main types of battery are available: lead-acid, nickel-iron, nickel-cadmium, silver-zinc, silver-cadmium, and fuel cells. With the intention of evaluating the status of the lead battery in relation to competitive types, the authors review in this paper the limitations and advantages of each, and present data comparing energy densities, estimated life, and estimated cost per cycle, and information on battery sales and battery-metal production in the U.S.A. in 1959.

Nickel-Cadmium Cells With a High Energy/Weight Ratio

J. C. DUDDY and A. J. SALKIND: 'High Energy: Weight Ratio, Nickel–Cadmium Cells.'

Jnl. Electrochemical Soc., 1961, vol. 108, Aug., pp. 717–9.

In conventional nickel–cadmium cells, the active materials are contained in the pores of sintered nickel plaques or in nickel or nickel-plated-steel tubes or pockets. Cells of sintered-plate and pocket type have energy/weight ratios of, respectively, approximately 27 and 25 whr./kg. Theoretically, however, the active materials could deliver 250 whr./kg., the reduction in energy density being due to the presence of electrolyte, separators, cell cases, hardware, and the supporting structure for the active materials. A considerable portion of the weight of conventional nickel–cadmium cells is taken up by the supporting structure, and this fact induced the authors to investigate the feasibility of developing a light-weight supporting structure for the active materials. The scope of the investigation, and the success achieved, are reported in the present paper.

Plastic matrices, although not suitable for many electrode materials, are of value in nickel-cadmium cells, since the upper storage temperature imposed by the nickel electrodes is lower than the flow temperature of the matrix materials commonly available. The plastic electrodes developed by the authors were produced by intimately mixing two incompatible polymers on a rubber mill, and loading the polymer blends with active materials. One of the two polymers was chosen so as to be soluble in some inexpensive solution; the other was insoluble in the extraction solvent, and served as a residual binding agent. When the extraction was to be done by water, the extractable polymer contained polar groups, usually hydroxyl groups, and did not have a very high degree of polymerization. The extraction of leachable polymers created capillary forces within the sheets of electrode material, which were supplemented by the swelling of the polymer in the early stages of wetting by the solvent. Since the active material and residual plastic provided only non-rigid walls, the mix sheets swelled 5–50 per cent. on wetting, resulting in electrodes with much greater porosity than that arising from the simple extraction of the soluble plastic. The average pore size of the electrodes produced by this technique was less than 1μ, but the total porosity was between 10 and 50 per cent. of the volume of the electrode.

Details are given of the materials and procedures involved in the preparation of cadmium and nickel electrodes, and data illustrating performance characteristics are included in the paper. Cells incorporating the nickel and cadmium electrodes described are stated to have exhibited an energy density of 40 whr./kg., a value which a moderate improvement in electrode efficiency could, it is believed, increase to 50 whr./kg.

ELECTRODEPOSITION AND OTHER COATING METHODS

Corrosion-Resistance of Copper/Nickel/Chromium Coatings on Steel

J. ELZE: 'Corrosion of the Copper/Nickel/Chromium Coating System on Steel.'

Galvanotechnik, 1961, vol. 52, Feb. 12., pp. 59–68.

Polarization curves determined, in previous studies, for the matt-nickel/chromium system in a neutral aqueous solution indicate that matt-nickel electrodeposited coatings do not form a corrosion cell with the more noble chromium, and the combination does not therefore lead to accelerated corrosion of the nickel. Whether the chromium overcoating is crack-free or not is therefore of no practical significance. With a bright-nickel/chromium combination, however, a corrosion cell does form, resulting in accelerated corrosion of the nickel. It follows, in general, therefore, that with bright nickel the chromium overcoating should be as crack-free as possible. With the aim of contributing to the understanding of the corrosion-resistance of the copper/nickel/chromium system, the author undertook, in the work now reported, a laboratory investigation of the resistance of various combinations of copper, nickel and chromium coatings to various corrosive solutions.

The combinations selected for study are noted below:

(1) On a steel substrate: copper; matt nickel; bright nickel; porous nickel containing organic impurities; chromium.

(2) On a copper substrate: copper/matt nickel; copper/bright nickel; copper/porous nickel; copper/chromium; copper.

(3) On a nickel substrate: matt nickel/chromium; bright nickel/chromium; porous nickel/chromium; matt nickel; bright nickel; porous nickel.

Steel and electrodeposited-chromium specimens were also tested.

The specimens were exposed to the following media: (*a*) a phthalate-buffered solution (pH 6·0) representing a water environment; (*b*) a solution (pH 7·9) simulating sea water; (*c*) sulphurous acid (pH 2·9) representing 'industrial air'. Hydrogen-saturated air was blown through solutions (*a*) and (*b*). The test temperature varied from 22°–25°C. After 72 hours' exposure, the solutions were analyzed to determine the metal contents, and corrosion rates were then calculated in g./m.^{2}/day.

The data presented are discussed in terms of (1) the corrosion of the steel substrate, the copper coating and the nickel coating; (2) the influence of the chromium overcoating on the corrosion-resistance of matt nickel and bright nickel; and (3) their practical significance. Consideration of the data leads the author to draw the following conclusions:

(1) Copper, matt-nickel and bright-nickel electrodeposited coatings must be as impervious as possible to protect the steel substrate against corrosion: the corrosion cell which otherwise results leads to a sharp increase in the corrosion rate of the steel at locations where the coatings are not sufficiently dense (pitting corrosion).

(2) In sea water or in a sea-coast environment a copper undercoating plated with nickel becomes subject to pitting corrosion at porosities in the nickel coating, irrespective of whether the nickel coating is matt or bright.

(3) During exposure to rain water, porosity in the nickel coating of a copper/nickel composite does not result in a corrosion cell, provided that the nickel is of matt type. With copper/bright-nickel coatings, however, the bright-nickel layer will be severely attacked, due to the formation of a corrosion cell.

(4) Matt-nickel coatings are resistant to sea-coast environments or to the effects of rain water, and the rate of attack in the region of the cracks existing in a bright-chromium overcoating is not increased by a corrosion-cell effect. Even cracked-chromium overcoatings confer on matt-nickel coatings a considerable degree of protection against these atmospheres.

(5) Exposure to rain water considerably increases the corrosion rate of bright-nickel coatings in contact with chromium overcoatings. Bright-nickel deposits coated with cracked chromium suffer deep pitting in the region of the cracks. The chromium overcoating, which *per se* is corrosion-resistant, is gradually undermined and exfoliated.

(6) Both matt- and bright-nickel coatings are subject to attack in sulphurous acid, and, for all practical purposes, can no more be regarded as protective coatings.

Nickel-plated or copper/nickel-plated components which are subjected to SO_2-containing industrial atmospheres must be plated with absolutely dense (i.e., crack-free) chromium.

(7) The chromium electrodeposit was not attacked by any of the three test media during an exposure time of 72 hours, irrespective of whether it was exposed as a single specimen or in combination with steel, nickel or copper.

Corrosion Protection of Nickel/Chromium Electrodeposited Coatings

In recent years much attention has been given to methods of increasing the corrosion-resistance of decorative chromium/nickel electrodeposited coatings. In view of the progress which has been made in this direction, and to outline the approaches which are now being followed, *Galvanotechnik*, 1961, vol. 52, July 15, is given up to a series of articles on the theme 'Improved Corrosion Protection by Composite Metal Coatings'. The scope of the papers contained in the issue is indicated in the abstracts below.

Decorative Nickel/Chromium Plating in the U.S.A.

F. LAQUE and C. H. SAMPLE: 'Decorative Nickel/Chromium Plating in the United States', pp. 340–3.

Reviewing the factors which led to present-day developments in nickel/chromium plating in the United States, the authors refer to the recognition that bright-nickel coatings exhibit lower corrosion-resistance than the previously used buffed matt-nickel sulphur-free deposits, and the finding that the SO_2 test is not a satisfactory criterion of service performance. The use of the 'Corrodkote' and CASS tests subsequently evolved threw light on the corrosion behaviour of bright-nickel/chromium coatings and revealed the beneficial effect of thicker chromium overcoatings and copper undercoatings (provided, in the latter case, the nickel/chromium combination, *per se*, offers satisfactory corrosion-resistance).

In the final section of their short review, the authors concern themselves with the advantages of double-layer-nickel plating and the acceptance the system is now finding in the U.S.A. The increased corrosion protection associated with the use of thicker chromium overcoatings is referred to, but, in view of the relatively unfavourable current efficiency of present-day chromium-plating processes, economic factors will tend, it is considered, to militate against the use of substantially thicker chromium coatings (especially, it is stated, when equal or greater corrosion protection can be achieved by using thicker double-layer nickel coatings under chromium of conventional 0·25–0·5μ thickness). The use of thicker chromium overcoatings (whether crack-free, microcracked, double-layer or single-layer) will therefore depend on whether the financial outlay involved is considered worthwhile in terms of the increased corrosion protection obtained.

Corrosion Behaviour and Levelling Performance of Bright-Nickel and Double-Layer Nickel Deposits

W. NOHSE, H. MÜLLER and U. STÖCKER: 'Comparative Study of Corrosion Behaviour, with Particular Reference to the Chromium Layer and Levelling in Single- and Double-Layer Nickel Coatings', pp. 344–54.

The experiments reported were undertaken with two aims in mind: (1) to determine whether the corrosion behaviour of specimens coated with double-layer nickel would, in accelerated-corrosion tests, differ from those coated with bright-nickel; (2) to compare the levelling effect of double-layer and bright-nickel coatings, and also to compare the levelling performance of a copper undercoating with that of the subsequent nickel coating.

In phase (1) of the study the plated specimens (steel and zinc-base die castings) were exposed to the 'Corrodkote' test, the ferroxyl test and the Kesternich test: photomicrographs illustrating the corrosion behaviour of the various coatings are included in the paper. The effect of a chromium overcoating was given particular consideration.

In phase (2) levelling performance was compared by metallographic examination of zinc-base die castings plated with copper + double-layer nickel + bright chromium or with copper + bright nickel. Levelling capacity was assessed in relation to three basis-metal surface conditions, involving: (1) cavities in the polished surface, (2) unevenness representative of an untreated surface, and (3) the presence of artificially introduced pores. Photomicrographs of the plated specimens are presented, together with drawings illustrating the thickness measurements made by the authors during metallographic examination.

Study of the corrosion process associated with single- and double-layer nickel in phase (1) of the test programme led to the following findings:

(1) With a thin overcoating of chromium which does not bridge over the corrosion pit formed in the nickel coating as corrosion progresses in the bright-nickel layer, double-layer nickel protects the basis metal against attack in the ferroxyl and Kesternich tests. In particular, double-layer nickel decreases blistering on zinc-base die castings.

(2) With thicker chromium overcoatings, double-layer nickel confers less protection on the basis metal, due to the formation of chromium 'bridges' which promote penetrative corrosion.

(3) A chromium layer relatively free from cracks and porosity is superior to a conventional chromium coating of the same thickness.

From the second phase of the study the authors draw three main conclusions:

(1) Complete levelling is not obtained with double-layer-nickel/chromium coatings on unpolished zinc-base die castings, and brightness is not satisfactory.

(2) In terms of levelling effect, double-layer nickel is slightly superior to single-layer nickel.

(3) The levelling capacity of double-layer nickel and bright nickel is considerably greater than that of cyanide copper.

Crack-Free and Microcracked Chromium Overcoatings

R. BRUGGER and G. VOSS: 'Chromium Plating and Corrosion Protection', pp. 355–8.

In this review the authors are concerned with the possibility of improving the corrosion-resistance of nickel/chromium decorative coatings by means of (1) crack-free and pore-free chromium overcoatings, and (2) microcracked chromium overcoatings.

In discussing crack-free chromium coatings, the authors allude to the difficulties encountered in attempts to obtain, from one and the same solution, deposits which are both crack-free and free from porosity, and the main portion of the article is therefore given up to consideration of the features and advantages of microcracked chromium. The presence of a large number of microcracks in an overcoating of this type has the effect of presenting a large chromium surface in contact with a large nickel surface, and thus of considerably decreasing the corrosion current density at the anode (i.e., the nickel); with an overcoating of conventional coarse-cracked chromium, or of crack-free chromium containing a small number of pores, a relatively small nickel surface is in contact with a large chromium surface, and the current density at the anode is high. The two methods of depositing microcracked chromium (duplex-chromium plating, and plating from specially developed solutions) are commented upon. For optimum results, the component must, it is stated, be chromium plated long enough to ensure formation of the crack network over the whole surface, involving, in some cases, up to fourteen minutes' plating at a suitably high current density.

Significance of Thick Chromium Coatings

J. A. BECHTOLD: 'The Significance of Thick Chromium Deposits', pp. 359–62.

The author first discusses the electrochemical reactions involved in corrosion of a bright-nickel/thin-chromium coating combination, and then outlines the 'significance', in this connexion, of ensuring that the chromium overcoating (1) is thick enough to be free from porosity, and (2) contains no cracks (or at least none which penetrates directly to the underlying metal). He refers to the development of plating solutions capable of depositing chromium coatings which are both crack-free and several times as thick as those previously available, and finally considers the development of double-layer (crack-free + cracked) chromium, and the reasons for the increased protection attainable by its use as an overcoating. Economic considerations are regarded as a major factor in determining the degree to which both types of thicker chromium coating find acceptance.

Corrosion Protection of Various Electrodeposited Coating Systems

W. METZGER: 'The Possibility of Improving Corrosion Protection by Electrodeposition of Metals, with Particular Reference to the Car Industry. Part II', pp. 363–73.

The present paper is based on data derived from corrosion tests carried out by the Udylite Corporation, Detroit, and Friedr. Blasberg, Solingen-Merscheid, and on information obtained in co-operative work with automobile companies. In Part I of the paper (*ibid.*, May 15, pp. 227–36), the author discussed the electrodeposition and general corrosion behaviour of the following coating systems: (1) copper + nickel + crack-free or microcracked chromium; (2) double-layer nickel; (3) double-layer chromium; (4) composite coatings (chromium + nickel + chromium, copper + chromium + nickel + chromium, and nickel + chromium + nickel + chromium). The corrosion process was illustrated by reference to photomicrographs included in the paper.

Part II is concerned with data derived from atmospheric-exposure and accelerated-corrosion tests carried out on specimens plated with coatings including the same systems as in Part I.

After discussing the various tests employed in evaluating the quality of electrodeposited coatings (accelerated tests, static atmospheric-corrosion tests, mobile atmospheric-corrosion tests), the author discusses corrosion data derived from static-exposure and mobile-exposure tests (in the latter, plated specimens and hub-caps were exposed on cars driven in

various American cities) carried out by the Udylite Corporation in recent years.

To obtain information on the corrosion behaviour of the new coating systems, and to examine the degree to which the results of the Kesternich accelerated-corrosion test agree with those obtained from static atmospheric exposure and the 'Corrodkote' test, the author initiated a test programme in which (*a*) plated hub-caps were exposed on a roof in Solingen during the winter, and (*b*) specimens were subjected to each of the accelerated-corrosion tests. The following coating systems were studied: buffed or unbuffed copper + bright nickel + crack-free chromium; buffed copper + bright nickel + bright chromium; buffed copper + double-layer nickel + crack-free chromium; double-layer nickel + crack-free or bright chromium; bright nickel + crack-free chromium; buffed copper + bright nickel + crack-free chromium + microcracked chromium; buffed copper + bright nickel + microcracked chromium + crack-free chromium; buffed copper + microcracked chromium + bright nickel + crack-free chromium.

The data presented in the paper are deemed to justify the following conclusions:

(1) The short- and long-time corrosion tests (including four years' exposure to the atmosphere) show the 'sandwich' coating system incorporating an intermediate layer of chromium to be extremely resistant to corrosion.

(2) Except in the Kesternich test, double-layer chromium exhibits exceptional performance, but during atmospheric exposure the coatings tend to become matt.

(3) In terms of the Kesternich test and exposure in an industrial atmosphere, double-layer nickel offers no great advantages, but, when assessed in terms of the 'Corrodkote' test and mobile atmospheric-exposure tests, corrosion protection is much higher.

(4) Where use is made of thicker chromium coatings (including double-layer chromium), a copper underlayer should not be excluded. A ductile bright-nickel-plating solution with the highest possible brightening effect should also be employed.

(5) The results of the 'Corrodkote' and CASS tests agree with those obtained from static atmospheric exposure in marine atmospheres, or those obtained in mobile tests in towns in which salt is strewn on the streets during winter. The Kesternich test, on the other hand, produces results similar to those obtained in tests involving exposure to severe industrial atmospheres.

In his overall conclusions, the author considers the greatest disadvantage of double-layer chromium, compared with double-layer nickel, to be the length of time necessary to deposit a sufficiently thick coating. In districts involving exposure to severe industrial atmospheres, and in which salt is *not* strewn on the streets in winter, double chromium is superior to a double-layer-nickel system. In marine atmospheres or in towns in which salt is strewn in winter (as, for example, is customary in the northern cities of the U.S.A., and also, to an increasing extent, in Germany), the performance of double-layer nickel coatings is very good.

In the final section of the paper the author discusses the acceptance which the new plating techniques are finding in Europe and in the U.S.A.

Copper as an Intermediate Layer in Electrodeposited Coatings

H. W. DETTNER: 'Copper as an Intermediate Layer in Composite Metal Coatings', pp. 374–6.

The author discusses the significance of the copper constituent in the copper/nickel/chromium coating system in the light of the introduction of the double-layer-nickel/chromium system and the feasibility of gaining equal or better corrosion protection by a copper + nickel coating. He concludes that an adequately thick copper undercoating plays a valuable rôle in protecting the basis metal against corrosive attack, and that, in particular, copper is more resistant to sulphur-containing (i.e., industrial) atmospheres than nickel. Copper, moreover, offers the advantages of good adhesion and low cost.

The Copper Undercoating in Copper/Nickel/Chromium Coatings

E. ROTH: 'The Copper Undercoating in Copper/Nickel/Chromium Deposits', pp. 377–84.

In the introductory section of his paper, the author lists the main conclusions which can be drawn from work in recent years on the protective value of copper/nickel/chromium electrodeposited coatings. Two of the seven findings listed are (1) that (assuming the same total coating thickness) the matt-nickel/bright-nickel/chromium system is superior to the copper/nickel/chromium system, and (2) that an intermediate layer of copper makes a real contribution to corrosion-resistance in very few cases. The results obtained by application of the various findings to the field of practical plating have, in his experience, not proved as reproducible as might have been expected, and this paper was written to indicate the pitfalls inherent in an evaluation of such findings on a mainly phenomenological basis.

The author first considers, in general terms, the variables which might render results for corrosion-resistance irreproducible, and therefore, possibly, fallacious. In this connexion, attention is directed to the influence of the basis metal, pre-plating treatments, rinsing processes incorporated in the plating cycle, variations in the composition of commercial plating solutions and in the conditions under which they are operated, and changes in the electrolyte during plating.

The concluding section of the paper is given up to a discussion of a particular example of ways in which data on corrosion-resistance can, in certain respects, differ from those obtained in previous studies. To determine the influence of a copper undercoating on the corrosion-resistance of nickel/chromium

coatings, sections of car bumpers were plated with an undercoating of copper (from an acid bright-plating solution or from a cyanide solution), buffed or left unbuffed, bright-nickel-plated, and finally chromium-plated. Other specimens were coated with a bright - nickel/chromium or matt - nickel/chromium combination. The total coating was about 25μ thick, of which the chromium overcoating comprised 0·5μ.

Data obtained from the Kesternich test lead the author to the unexpected conclusion that the coatings incorporating buffed copper were inferior in corrosion-resistance to those with unbuffed copper (this finding is explained in terms of metal loss during buffing). Supplementary experiments showed that, provided the copper undercoating is pore-free and thick (25μ), buffing has no influence on corrosion-resistance. It is stated that a copper/nickel/chromium system containing a sufficiently thick pore-free undercoating of copper conforms to the requirements of a corrosion-resistant double-layer-nickel/chromium coating since, like matt nickel, copper deposits are cathodic to bright-nickel deposits.

As a further advantage of copper coatings the author cites the excellent levelling characteristics obtainable with copper coatings deposited from recently developed acid bright-plating solutions.

Improvements in the Nickel Plating of Zinc-base Die Castings

B. J. KUILENBERG: 'Improved Electroplating of Zinc Die Castings', pp. 385–9.

In recent years much attention has been given to the problem of improving the corrosion protection conferred on zinc-base die castings by nickel/chromium electrodeposited coatings, and eliminating such defects as blistering. In the belief that the nickel-plating technique must be regarded as the factor of greatest consequence in this respect, the author discusses the salient features of the double-layer-nickel process, the corrosion behaviour of the double-layer system, and the increased corrosion protection which can be achieved by applying the technique to the plating of zinc-base die castings. A typical plating sequence is listed.

Study of Extremely Thin Nickel Coatings

A. KUTZELNIGG and H. LAUB: 'Electrodeposited and Chemically Deposited Nickel Films in the Thickness Range up to 300Å.'

Metalloberfläche, 1961, vol. 15, June, pp. 161–4.

In the investigation reported, the authors studied the electrodeposition, chemical deposition, and the characteristics of extremely thin nickel coatings.

The coatings (deposited on a copper substrate) behaved like the massive metal only at a thickness in the region of 140–200Å and above, and at a thickness of approximately 140Å were practically invisible and, under electron-microscopical examination, homogeneous and structureless. The homogeneity of the coatings was found to be independent of current density in the range 0·05–4 amp./dm.^{2} and of the type of nickel electrolyte employed. The time law for the thermal oxidation of coatings less than 140 Å thick differed from that for massive nickel and copper. From the practical point of view, the data are regarded as demonstrating that a thin electrodeposited coating need not necessarily be porous.

Details are given of the apparatus used to achieve deposition times in the region of a tenth of a second, and a method for colorimetric determination of nickel in microgram amounts is described.

Levelling in Bright-Nickel-Plating Solutions

S. E. BEACOM and B. J. RILEY: 'Mechanism of Addition Agent Reaction In Bright and Leveling Nickel Deposition. I. Studies With Radioactive Sodium Allyl Sulfonate.'

Jnl. Electrochemical Soc., 1961, vol. 108, Aug., pp. 758–63.

In previous papers (see abstracts in *Nickel Bulletin*, 1959, vol. 32, No. 6, p. 177; 1960, vol. 33, No. 11, p. 272), the authors demonstrated, on the basis of data obtained by radiotracer techniques, that the organic addition, sodium allyl sulphonate, which imparts levelling characteristics to a bright-nickel-plating solution, is adsorbed onto the high points of an irregular surface, a finding which was regarded as verification of a part of a levelling theory which assumes that the levelling process is initiated by such preferential adsorption.

Since it was known that the radioactive addition agents are included in the nickel deposits, it was deemed important to consider in what form they are included. Evidence has been presented to show that the sulphonate group of sodium allyl sulphonate is reduced to sulphide, and included as such in nickel deposits, and it was therefore deemed necessary to consider how the allyl sulphonate molecule is broken down or cleaved to permit such a reduction. Investigation of this factor would require tagging of both ends of the molecule, so as to determine the ratio of sulphur to nickel and carbon to nickel included in the deposits. In the present investigation, the study of the levelling phenomenon in nickel plating was extended to include examination of nickel coatings deposited in the presence of sodium allyl sulphonate tagged with S-35 or C-14.

Reduction of sulphonate to sulphide was studied polarographically, and identification of sulphide in the nickel deposits was effected by a qualitative test. Cleavage of the addition agent was studied by examination of the gaseous products obtained during the electrodeposition of nickel.

Since data presented by the authors demonstrate that, in the presence of the addition agents sodium allyl sulphonate and N-allyl quinaldine bromide, a

synergistic effect occurs in levelling, a study was also made of the interactions between the two, and the amount of the allyl sulphonate or its reduction product included in the nickel deposit was determined as a function of the concentration of the other compound.

The authors suggest that organic addition agents probably undergo a step-wise sequence of adsorption, cleavage and reduction. Their consideration of the data leads them to propose a model in explanation of the synergistic effect on levelling brought about by combinations of addition agents.

Influence of Various Combinations of Brightening Agents on the Characteristics of Electroless Nickel-Plating Solutions

W. MACHU and S. EL-GENDI: 'Effect of Mixtures of Several Brightening Agents In Electrolessly Operated Nickel-Plating Solutions. Part II.'

Werkstoffe u. Korrosion, 1961, vol. 12, June, pp. 363–8.

Nickel coatings deposited from the electrolessly operated sodium-hypophosphite solution are matt, although extremely fine-grained. In previous papers, the authors discussed the results of experiments carried out to determine the influence of (1) inorganic and (2) organic brightening agents on the appearance and properties of nickel deposited from the solution (see abstracts in (1) *Nickel Bulletin*, 1959, vol. 32, No. 7, pp. 212–3, and (2) *ibid.*, 1961, vol. 34, No. 7–8, pp. 179–80). In the experiments now reported, the scope of the research was extended to include investigation of the effects of introducing two or more organic brighteners, or mixtures of organic and inorganic brighteners, into the plating solution.

Aluminium specimens were plated with nickel for 1 hour in a solution operated at 90°C. and containing nickel chloride 30, sodium hypophosphite 10, sodium citrate 97·5, ammonium chloride 47·5, g./L. The pH was adjusted to 9·15 with ammonium hydroxide. The effects of adding organic agents (e.g. p-toluene sulphonamide, saccharin, caffeine, theobromine) and mixtures of organic and inorganic agents (the inorganic agents including cobalt acetate and uranium acetate) to the solution were assessed in terms of the brightness and weight of the coatings produced.

The presence of brighteners led, it was found, to the formation of a film or diaphragm on the metal surface which acted like an inhibitor and somewhat reduced the amount of metal deposited. When several brighteners were simultaneously present, the one whose adsorption or chemisorption released the greatest amount of energy was preferentially adsorbed or chemisorbed. This agent then influenced the weight, as well as the brightness, of the nickel deposited. Wetting agents were observed to oust the brighteners from the metal surface, but did not give rise to a diaphragm promoting brightness.

Influence of Thiourea on the Deposition Reactions of Iron and Nickel

R. D. DEMARS: 'Influence of Thiourea on the Deposition Reactions of Iron and Nickel.'

Jnl. Electrochemical Soc., 1961, vol. 108, Aug., pp. 779–82.

The addition of thiourea to plating solutions as a means of varying the physical properties of the deposits is a well-established technique. In the work now described the author made a polarographic study of the deposition reactions of iron and nickel in solutions containing (1) the relevant metal ion and potassium chloride, and (2) the relevant metal ion, potassium chloride and thiourea. Deposition of iron-nickel films from mixed chloride solutions containing thiourea was also investigated. Analysis of the polarographic waves yielded values for the kinetic parameters, αn_a and $k^\circ_{f,h}$, for the reduction reactions, and the influence of temperature and thiourea concentration on these parameters was studied.

The effect of thiourea on the relative rates of cathodic deposition of iron and nickel from mixed chloride solutions was found to be paralleled by the effects of thiourea on the polarographic waves in the separate solutions of the ferrous and nickelous chlorides. The data obtained for the basic deposition reactions of iron and nickel in such solutions enabled the author to speculate on the composition behaviour of iron-nickel films deposited from similar solutions, and, in the case of the particular solutions studied, the predictions made appear to be substantiated by data derived from deposition of a series of iron-nickel films in a supplementary phase of the investigation.

Deposition of Nickel from a Liquid-Metal Solution

G. DEVRIES: 'Plating from Liquid Metal Solutions.'

Metal Progress, 1961, vol. 79, June, p. 114.

In this 'letter to the editor', the writer draws attention to the feasibility of plating metals from a liquid-metal solution.

During an investigation of the corrosion of metals by molten lithium in 1951, it was noted that nickel had the ability to go into solution in the lithium and then plate out on to other metals. To study this phenomenon further, small pieces of 'Monel', nickel, 'Nichrome V', titanium, Type 347 18–11–Nb stainless steel, Type 416 13 per cent. chromium stainless steel, and A.I.S.I. 4130 chromium-molybdenum low-alloy steel were placed in a cup fabricated from A.I.S.I. 1042 carbon steel. The cup was then filled with molten lithium, heated, under helium (at 200–300 p.s.i.) for 72 hours at 900°F. (480°C.) in an electric resistance furnace, and finally cooled in the furnace. Microscopical examination of the specimens showed that the ferritic steels, A.I.S.I. 1042 and 4130 and Type 416, were plated with a thin adherent coating which appeared to be nickel. The A.I.S.I. 1042 steel was decarburized under

the plating, but no attack was observed on the other two steels. 'Nichrome V', titanium and Type 347 steel were not corroded or plated. 'Monel' and nickel were attacked, and a large part of the 'Monel' had dissolved.

In another test, a nickel cup containing a nickel rod and a specimen of A.I.S.I. 1042 steel was filled with lithium and held at 900°F. (480°C.) for 72 hours under an atmosphere of helium. The nickel specimen was subsequently found to have suffered a loss in weight, while the A.I.S.I. 1042 specimen had gained in weight. The nickel dissolved in the lithium, some of it depositing on the steel. A similar test at 600°–700°F. (315°–370°C.) in the same furnace resulted in a much thinner deposit on the steel.

Other metals also can, it is said, be plated from liquid-metal solutions. Chromium can, for example, be plated onto molybdenum from a liquid solution in tin or copper. Nickel can be plated onto chromium from a liquid solution in lead.

Electrodeposition of Nickel-Iron Alloys from the Pyrophosphate Solution

V. SREE and T. L. R. CHAR: 'Electrodeposition of Nickel-Iron Alloys from the Pyrophosphate Bath.'

Metal Finishing, 1961, vol. 59, Aug., pp. 49–55.

This paper is one of a series describing experiments carried out to study the electrodeposition of various metals and alloys from pyrophosphate solutions: abstracts of recent papers relating to deposition of nickel–zinc, nickel–cobalt, nickel–copper and nickel–tungsten alloys were published in *Nickel Bulletin*, 1961, vol. 34, No. 2, p. 32; No. 4, p. 90; No. 5, pp. 118 and 119. In the continuance of the investigation now reported, the authors were concerned with the establishment of optimum plating conditions for electrodeposition of nickel–iron alloys.

Alloy deposition was carried out under conditions differing with respect to electrolyte composition, addition agent, pH, and temperature, and a detailed study was made of the effect of plating variables on deposit composition, cathode efficiency, and cathode potential. The results of this study are discussed detail.

The solution was found to produce bright, adherent, smooth deposits containing 4–87 per cent. nickel, the colour ranging from dull grey to bright white with increase in nickel content. The bath was stable under the experimental conditions studied. The operating conditions established as optimum, and plating characteristics under optimum conditions, are listed below.

Solution composition	*g./L.*
Nickel chloride ($NiCl_2 \cdot 6H_2O$) ..	71·4
Ferric chloride ($FeCl_3 \cdot 6H_2O$) ..	27·0
Pyrophosphate (P_2O_7)= ..	174·0 (1·0M)
Nickel	17·6 (0·3M)
Iron	5·6 (0·1M)
pH	8·3
Temperature, °C.	60
Sp. resistance, ohm. cm./cm.² ..	4·81
Bath voltage	0·9–1·6
Agitation, r.p.m.	—
Cathode	Pt, Cu
Anode, % Ni	74
Cathode c.d., amp./dm.²	0·35–3·5
Anode c.d., amp./dm.²	0·09–0·90
Cathode efficiency, %	32–41
Anode efficiency, %	63
Cathode potential, v.	0·76–0·96
Anode potential, v.	0·01–0·23
Throwing number, N	0·1949
Deposit composition, % Ni ..	40–71
Time to deposit 0·0005 in. (min. at 2·1 amp./dm.²) ..	88

Thermoelectric Gauge for Determining the Thickness of Nickel Coatings

P. M. REYNOLDS: 'Non-destructive Method of Gauging Electrodeposited Nickel Layers.'

Jnl. Scientific Instruments, 1961, vol. 38, Aug., pp. 313–17.

B.S. 1224: 1959, covering nickel/chromium electrodeposited coatings, specifies minimum local thicknesses of nickel for particular combinations of basis metals and service conditions. This requirement has led to a demand for a rapid, inexpensive and non-destructive method of measuring the local nickel thickness, with an accuracy of ±0·1 mil, on complex surfaces at any point which can be touched by a ball of 1-in. (2·5-cm.) diameter. The British Non-Ferrous Metals Research Association has developed a technique, which, utilizing the local thermal e.m.f.'s set up when a heated metal probe is brought into contact with the coating, can be used to measure the thickness of electrodeposited nickel from 0·2 to at least 1·5 mil thick. In this paper details are given of the principle, design and calibration of the thermoelectric gauge. The accuracy of the instrument is discussed in relation to an evaluation of the influence of the differing thermoelectric properties of various commercial nickel deposits, and finally the results of extensive industrial tests on the commercial version of the gauge are summarized.

Readings can be taken at 5-second intervals, and industrial trials on parts from automatic plating baths show that, within the thickness range 0·1–1·5 mil, the accuracy of the instrument is as follows:

nickel on steel	±0·1 mil;
nickel on copper on steel ..	±0·15 mil;
nickel on copper on zinc ..	±0·1 mil.

It has not yet been possible to conduct commercial tests for nickel deposits on brass, but laboratory tests indicate that an accuracy of ±0·1 mil should be obtainable with suitable calibration. The instrument is essentially for application to industrial control, and is not suitable for use with nickel deposits of unknown origin.

Determination of Zinc in Nickel Electrolytes

L. DOMNIKOV: 'Determination of Zinc in Nickel Electrolytes.'

Metal Finishing, 1961, vol. 59, Aug., p. 69.

In this article the author outlines a method of determining zinc in nickel electrolytes developed by workers at Moscow Polygraphic Institute from the procedure proposed by V. I. KUZNETSOV and based on the colour change of methyl violet indicator in the presence of the metal. (The reaction sensitivity of methyl violet indicator with zinc can be regarded as 0·0005 per cent., a value ten times smaller than the zinc concentration permissible in nickel electrolytes.)

The method of analysis involves mixing, in a test tube, 25 drops of water, 5 drops of a saturated tartaric-acid solution, 2 drops of hydrochloric acid (specific gravity 1·2), 4 drops of a 20 per cent. solution of ammonium thiocyanate, and 6 drops of a 0·06 per cent. solution of methyl violet indicator. The contents of the test tube are divided into three portions. One is retained for the purposes of comparison. To the second are added 2 drops of nickel solution: if the bath contains zinc, the bluish-green colour of the solution will change to violet (or to blue with small zinc concentrations), indicating that zinc is present in an amount equal to or exceeding 0·0005 per cent.

To determine whether the zinc concentration does or does not exceed the permissible value, the sample taken from the bath is diluted to one-tenth of its original strength, and 2–3 drops of this diluted solution are added to the third test tube with the reagent. The change of colour from greenish blue to violet indicates that the concentration of $zinc^{++}$ is 0·005 per cent., and that the plating solution requires purifying.

For quantitative zinc determination, the reagent is freshly prepared and divided into three portions. The plating solution is diluted to one twentieth, one thirtieth and one fortieth of its original strength, and analyses are carried out. If the colour change is detected with the one-thirtieth dilution and not with the one-fortieth, the zinc concentration in the bath is $0{\cdot}0005 \times 30 = 0{\cdot}015$ per cent. A table correlating zinc concentration with colour change is included in the article.

NON-FERROUS ALLOYS

Report of the Royal Mint: Nickel-containing Coinage

'Ninety-First Annual Report of the Deputy Master and Comptroller for the Year 1960.'

Published by *H.M. Stationery Office*, 1961; 92 pp. Price 7/-.

The report includes the usual statistical information on United Kingdom silver, cupro-nickel, nickel-brass and bronze coinage, currency withdrawn, assays made, and coinages produced for overseas countries. Details of the activities of the associated Mints in Australia are also given.

Coinage of completely new design struck at the Royal Mint during 1960 included: a completely new currency of six denominations in nickel-brass and bronze coinage for the Maldive Islands; a new currency of cupro-nickel and nickel-brass coinage in six denominations for Kuwait; and a cupro-nickel dollar piece for Hong-Kong. The decision of Uruguay to issue an entirely new coinage led to the placing of an order for 251 million pieces in the following six denominations (the order is the second largest ever received from overseas): cupro-nickel: 1 peso, 50 centesimos, 25 centesimos; nickel-brass: 10 centesimos, 5 centesimos, 2 centesimos. These coins, together with others, and the medals and seals struck during the year, are illustrated.

The withdrawal of the farthing and 'art and craft on coins' form two of the subjects discussed by the Comptroller in his report.

Intermediate Temperature Ductility Minimum in Metals

F. N. RHINES and P. J. WRAY: 'Investigation of the Intermediate Temperature Ductility Minimum in Metals.'

Trans. Amer. Soc. Metals, 1961, vol. 54, June, pp. 117–28.

To throw light on the causes of the brittleness range which occurs just below the recrystallization temperature in almost all ductile metals, and which once inspired the suggestion of 'equi-cohesive temperature', in the study reported the authors subjected the following normally ductile solid-solution alloys to a series of high-temperature tensile tests and to metallographic examination after testing: 'Monel', a pure 70–30 copper-nickel alloy, and cartridge brass.

On the basis of the data obtained, the brittleness range is attributed to the occurrence of grain-boundary shearing and associated intergranular rupture. Cavities, nucleating at four-grain intersections, grow intergranularly, as long as they lie upon shearing grain boundaries, thus decreasing the effective cross section of the metal and lowering its measured elongation and reduction-in-area. The growth of cavities, at normal rates of testing, is limited to temperatures above the beginning of recovery, where grain-boundary shearing becomes active, and below the recrystallization temperature, where the life expectancy of each grain boundary becomes so small that few remain associated with cavities long enough to produce growth. At very slow rates of testing, a second ductility minimum occurs at a somewhat higher temperature, where a critical relationship between the rates of recrystallization and grain-boundary migration again fosters cavity growth. These cases of lowered elongation are designated 'plastic brittleness', because they are characteristic only of highly ductile metals.

Gadolinium-Nickel System

V. F. NOVY, R. C. VICKERY and E. V. KLEBER: 'The Gadolinium-Nickel System.'

Trans. Metallurgical Soc., A.I.M.E., 1961, vol. 221, June, pp. 585–8.

In a continuation of investigations concerned with the properties of rare-earth alloys, the authors have studied the constitution of the gadolinium-nickel system. The results of these studies, and the constitutional diagram established for the system, are reported in the paper.

Little solubility of gadolinium in nickel or nickel in gadolinium was noted. Nine intermetallic compounds occur in the system at compositions corresponding to the following gadolinium/nickel ratios: 3/1, 3/2, 1/1, 1/2, 1/3, 2/7, 1/4, 1/5 and 2/17. The GdNi and $GdNi_5$ compounds have congruent melting points of 1300° and 1500°C., respectively, while the remaining compounds melt incongruently. Eutectics were found to exist at 15, 31·5 and 87 wt. per cent. nickel, with melting points of, respectively, 670°, 880° and 1220°C.

Study of the Titanium-Nickel System between Ti_2Ni and TiNi

G. R. PURDY and J. G. PARR: 'A Study of the Titanium-Nickel System between Ti_2Ni and TiNi.'

Trans. Metallurgical Soc., A.I.M.E., 1961, vol. 221, June, pp. 636–9.

The region of the titanium-nickel system corresponding to the phase TiNi has been the subject of several investigations. The study now reported was initiated to determine the phase diagram accurately between $TiNi_3$ and Ti_2Ni, and to attempt to resolve the differences between the reports of previous investigators.

The phase boundaries of TiNi were established by high-temperature X-ray diffraction and metallographic techniques. The data presented showed that the phase (centred at 51 per cent. nickel) has a restricted range of homogeneity at 500°C., and a much greater range at 800°C. In alloys containing less than 51 per cent. nickel, TiNi decomposed rapidly and reversibly at 36°C., to form a previously unreported phase designated π.

Structural Study of Ternary Alloys of Nickel and Nitrogen with Magnesium, Aluminium, Zinc and Cadmium

H. H. STADELMAIER and T. S. YUN: 'Nitrogen Alloys of the Transition Metals Manganese, Iron, Cobalt and Nickel with Magnesium, Aluminium, Zinc and Cadmium.'

Zeitsch. f. Metallkunde, 1961, vol. 52, July, pp. 477–80.

The authors investigated alloys of the following ternary systems for the presence of cubic nitrides: Mn-Mg-N, Mn-Al-N, Mn-Zn-N; Fe-Mg-N, Fe-Al-N, Fe-Zn-N; Co-Mg-N, Co-Al-N, Co-Zn-N; Ni-Mg-N, Ni-Al-N, Ni-Zn-N, Ni-Cd-N.

Ternary nitrides with a lattice of the $L'1_2$ type were observed in the Co-Zn-N, Ni-Al-N, and Ni-Zn-N systems. The data show that γ' iron nitride takes appreciable amounts of aluminium and zinc into solution, so that its homogeneity range is extended into the ternary system. In the Ni-Zn-N system two cubic nitrides were determined.

Structure and Properties of a Copper-Nickel-Silicon Age-Hardenable Alloy

W. D. ROBERTSON, E. G. GRENIER and V. F. NOLE: 'The Structure and Associated Properties of an Age-Hardening Copper Alloy.'

Trans. Metallurgical Soc., A.I.M.E., 1961, vol. 221, June, pp. 503–12.

Among the copper-base age-hardenable alloys, the copper-nickel-silicon age-hardenable alloy 'Silnic Bronze' is outstanding in exhibiting high strength in combination with a considerable capacity for cold working, a relatively high conductivity, and a low susceptibility to stress-corrosion cracking. The alloy has been the subject of a number of investigations, but these were primarily concerned with the establishment of compositional and heat-treatment limits, and the structural characteristics of the a geing process have not been studied in detail. The research now described was undertaken to explore, over a wide range of conditions, the properties obtainable by various combinations of working and heat-treatment, and to correlate structural changes with the mechanical, electrical and corrosion properties determined.

Specimens were prepared from eight commercial heats of alloy, falling within the following range of composition: copper 97·24–97·64, nickel 1·73–1·93, silicon 0·51–0·73, lead 0·01–0·005, iron 0·02–0·01, tin 0·01–0·005, manganese 0·02–0, zinc 0·01–0·2, wt. per cent. Hardness, conductivity and tensile properties were studied as a function of ageing time (and, in the case of the first two properties, ageing temperature) for both the quenched and quenched-and-cold-drawn conditions (ageing at 850°F. (455°C.) was established as optimum). The tensile properties and hardness of specimens subjected to various combinations of deformation and ageing were also determined, while other experiments were carried out to establish the stress-rupture, creep and elevated-temperature-tensile properties of specimens in the quenched-drawn-and-aged condition. Susceptibility to stress corrosion was investigated as a function of ageing time at 850°F.

The authors correlate the properties of the alloy with the structural characteristics observed during electron-microscopical examination of specimens in the following conditions: quenched; quenched and aged; quenched and deformed; quenched, deformed and aged; quenched, aged and deformed; and quenched, deformed, aged and deformed. Electron-micrographs are included in the paper in illustration of the microstructures associated with the different conditions of working and heat-treatment.

The precipitated phase was identified as Ni_3Si, and the sites of preferred precipitation were located. In the aged alloy an extreme form of deformation banding was observed which resulted in high strain concentration in bands lying parallel to (111) planes. These bands are the structural paths along which transcrystalline cracks propagate in the deformed alloy, and the observations provide a basis for an explanation of the general mechanism of transgranular corrosion cracking of face-centered-cubic alloys in terms of stacking fault probability.

Condensing Heat-Transfer Rates of Nickel-containing Condenser-Tube Materials

See abstract on p. 256.

NICKEL-IRON ALLOYS

Study of the Iron-Nickel-Gold Ternary System

W. KÖSTER and W. ULRICH: 'The Iron-Nickel-Gold Ternary System.'

Zeitsch. f. Metallkunde, 1961, vol. 52, June, pp. 383–91.

In the gold-nickel and gold-iron binary systems, miscibility gaps occur in the solid state, and age-hardenable alloys might therefore be expected to occur in the iron-nickel-gold ternary system. In the research now reported, the system was studied using thermal, microscopical, magnetic and dilatometric methods, supplemented by resistivity measurements.

The results show that the shape of the miscibility gap extending from the gold-nickel binary system into the ternary field remains virtually unchanged by additions of iron until it approaches the gold-iron side, where it widens to higher temperatures. Nickel additions were found to lower to room temperature the temperature of the ternary eutectoid reaction γ iron $\rightarrow \alpha$ iron + gold solid solution. The boundary for alloys participating in the α/γ transformation followed a line drawn from 28 wt. per cent. nickel on the iron-nickel side to the gold corner of the diagram.

The Curie temperatures of the ferromagnetic gold solid solutions in the gold-iron system were determined. The surface of the Curie temperature in the ternary γ solid-solution region was found to be shaped like a tunnel, its crest following a line from the maximum temperature in the iron-nickel system to the maximum temperature in the iron-gold system.

The breakdown of the unstable ternary solid solutions was studied in the range 500°–700°C. on a vertical section through the line connecting the gold corner with 52 wt. per cent. nickel in the iron-nickel system. The phase separation into a gold-poor iron-nickel solid solution and a gold-rich phase was accompanied by changes in the mechanical, electrical and magnetic properties. The activation energy of the precipitation process was in the region of 14·5 kcal./mol.

Study of Sigma Phase in the Iron-Nickel-Silicon System

S. TAKEDA, Y. IWAMA and A. SAKAKURA: 'Fundamental Research on Constant-Permeability Alloys. II. The Equilibrium Diagram of the Iron-Nickel-Silicon System, and the Ternary Compound σ Phase Appearing in the System.'

Nippon Kinzoku Gakkai-si, 1960, vol. 24, No. 8, pp. 534–8.

In the investigation described, the authors studied the constitution of ternary alloys of the iron-rich iron-nickel-silicon system by microscopy and magnetic and dilatometric analysis. The equilibrium diagram for solid-phase reactions was determined and is presented in the paper.

The σ phase reported in a previous paper was found to be ferromagnetic and was formed, after a eutectic reaction (melt $\rightarrow \alpha+\gamma$), by a peritectoid reaction ($\alpha+\gamma \rightarrow \sigma$) having a maximum temperature at about 920°C., at an original composition of approximately nickel 29, silicon 11, iron 60, per cent., corresponding to the formula $Fe_{11}Ni_5Si_4$.

The study showed the composition of the constant-permeability alloy 'Senperm' (which belongs to the system investigated) to extend over a region in which it exhibits a homogeneous α phase at higher temperatures, and then, due to change in solubility, precipitates σ phase as the temperature is lowered.

See also

Y. IWAMA and S. TAKEDA: 'Fundamental Research on Constant-Permeability Alloys. III. The Crystal Structure of a Ternary Compound σ Phase Appearing in 'Senperm' Alloys.'

Ibid., pp. 538–40.

Extending the scope of the work reported in the paper referred to in the previous abstract, the authors studied the crystal structure of σ phase, using X-ray-diffraction techniques. The density of an alloy consisting almost entirely of σ was also determined.

It was found that σ phase (1) has a crystal structure of simple cubic type with a lattice parameter $a_0 = 6{\cdot}148$Å, (2) has a density of 7·3 g./cc. at 17°C., and (3) contains 20 atoms, or one molecule of $Fe_{11}Ni_5Si_4$, in its unit cell.

Influence of Thiourea on the Deposition Reactions of Iron and Nickel

See abstract on p. 246.

Electrodeposition of Nickel-Iron Alloys from the Pyrophosphate Solution

See abstract on p. 247.

Influence of Heat-Treatment on the Permeability of Nickel-Iron Alloys

D. GERSTNER and E. KNELLER: 'The Diffusion After-Effect in the Permeability of Iron-Nickel Alloys.'

Zeitsch. f. Metallkunde, 1961, vol. 52, June, pp. 426–36.

The magnetic properties of the soft-magnetic nickel-iron alloys containing 50–80 wt. per cent. nickel are dependent to a great extent on the heat-treatment employed. After heat-treatment under hydrogen, with slow furnace cooling to room temperature, they exhibit relatively low permeability. The permeability of alloys quenched at an appropriate rate from approximately 600°C. is, however, extremely high, provided that cooling through the temperature range from the Curie point to about 300°C. is rapid. In the research reported, the authors studied the reactions occurring in this temperature range, paying particular attention to their relationship with permeability.

Tests were carried out on polycrystalline nickel-iron alloys containing 50–85 wt. per cent. nickel, to determine: (1) the initial permeability as a function of time during isothermal heat-treatment at various temperatures between 300°C. and the Curie temperature; (2) saturation magnetization and electrical resistance as a function of time during isothermal heat-treatment at 460°C.; and (3) the dependence of permeability on the field strength (up to approximately 1 Oe.) after heat-treatment for various times at the various temperatures at which the measurements were carried out.

In the absence of an external field, the initial permeability fell steadily as a result of heat-treatment in the range 300°–500°C. The activation energy established for this effect corresponded to that for diffusion of iron atoms in nickel-iron. The decrease in initial permeability was almost completely suppressed when the specimen was subjected to a magnetic field of constantly alternating direction during annealing. The permeability effect is therefore attributed to stabilization of the local magnetization directions by formation of a short-range directional order, according to the theory of Néel and Taniguchi and Yamamoto. The slight decrease in permeability observed in the presence of a field of constantly alternating direction is ascribed to the formation of a quasi-isotropic structural change (probably the formation of Ni_3Fe long-range order).

In principle, the same behaviour was found in '5-79 molybdenum Permalloy'.

Solubility of Nitrogen in Iron-Nickel Alloys at 1000°C.

H. A. WRIEDT and O. D. GONZALEZ: 'The Solubility of Nitrogen in Solid Iron-Nickel Alloys Near 1000°C.'

Trans. Metallurgical Soc., A.I.M.E., 1961, vol. 221, June, pp. 532–5.

In a recent investigation of the solubility of carbon in iron-nickel alloys at 1000°C. in gases of fixed carbon activity, an unpredicted minimum in the solubility was observed in the region of 72 per cent. nickel (see abstract in *Nickel Bulletin*, 1960, vol. 33, No. 6, p. 140). The present study was undertaken to determine whether a similar anomaly in solubility existed for nitrogen in iron-nickel alloys.

Pure iron, pure nickel and nickel-iron alloys containing 1·01–79·5 per cent. nickel were saturated with nitrogen gas at 918°, 919° and 1217°C. and analyzed, and the solubility of nitrogen at 1 atmosphere pressure was determined as a function of nickel content and temperature.

The solubility of nitrogen in pure iron at temperatures approaching 910°C. was slightly greater than that determined by other investigators, but good agreement was found at higher temperatures. The addition of nickel to iron markedly lowered nitrogen solubility at all the experimental temperatures, and, at nickel contents exceeding 70 per cent., nitrogen solubility was 0·0005 per cent. or less (compared with 0·02–0·03 per cent. in pure iron at the same temperatures). No minimum was detected in nitrogen solubility at any composition, but the experimental method employed is not considered sufficiently accurate at the high nickel levels to demonstrate the absence of a minimum.

Nitrogen solubility decreased in high-iron alloys, and increased in high-nickel alloys, with rise in temperature, but was independent of temperature at a composition in the region of 27 per cent. nickel. Corresponding to these temperature effects, the heat of solution of nitrogen was found to vary approximately from −3200 cal. per g-atom in pure iron to +3900 cal. per g-atom at 41 per cent. nickel. The entropy of solution of nitrogen in alloys with less than 41 per cent. nickel showed a slight composition effect. In these alloys the entropy change was of a magnitude (−10 cal. per degree per g-atom) corresponding to the loss of three translational degrees of freedom in going from a gaseous state to a condensed state. Minima are tentatively indicated in the heat of solution and in the entropy change when plotted against nickel content.

CAST IRON

Magnetic Properties of Nickel-containing S.G. Iron

H. DIETRICH: 'Magnetic Properties of S.G. Iron.'

VDI Berichte, 1961, No. 49, pp. 47–55.

In the work described the author (1) studied the magnetic properties of the ferromagnetic grades of

S.G. iron as a function of matrix structure and silicon and nickel contents, and (2) determined the room-temperature permeability of two grades of austenitic S.G. iron after exposure to low temperature and as a function of the rate of cooling after heat-treatment at 1000°C. Hardness and specific electrical resistance were also determined.

The percentage compositions of the grades of iron selected for study are noted below.

C	Si	Mn	Ni	Mg	Type
3·8	2·1	0·4	1·5	0·07	S.G. Iron
3·8	3·0	0·4	1·3	0·07	
3·8	2·1	0·3	trace	0·03	
3·8	3·0	0·4	trace	0·03	
2·8	2·5	6·8	11·2	0·17	Austenitic S.G. Iron
2·8	2·5	2·6	20·5	0·14	
3·4	1·7	0·85	0·6	—	Grey Iron
3·3	3·3	0·58	0·06	—	
0·04	0·01	0·02	0·11	—	Pure iron

The ferromagnetic grades of iron were heat-treated to produce a ferritic, ferritic/pearlitic, pearlitic, or quenched-and-tempered* structure. The austenitic grades were heated for 8 hours at 1000°C. and then cooled either in air, in the furnace or in water.

On the basis of the data presented in the paper, the author concludes that, in the ferritic condition, S.G. iron is a good soft magnetic material. In the pearlitic or hardened condition, its magnetic characteristics are not so satisfactory. The magnetic properties of ferritic S.G. iron were found to approach those of commercially pure iron, its coercive force falling within the range 1–2 Oe., its initial permeability in the range 300–500 G./Oe., and its maximum permeability in the range 1500–2000 G./Oe. Its specific electrical resistance was in the region of 0·6 (ohm mm.²/m.). Permeability was increased more than twofold when the silicon content was raised from 2 to 3 per cent., but was lowered by nickel additions. Electrical resistance and hardness increased with rise in silicon and nickel content. Ferritic S.G. iron can, it is therefore concluded, offer an unusual combination of satisfactory soft magnetic properties, high electrical resistance and good strength characteristics.

The data show that the permeability of austenitic S.G. iron, a non-magnetic material which couples the advantages of cast iron with the strength properties of cast steel, is very low, and, depending on the quality of the material and heat-treatment to which it is subjected, lies in the range 1·005–1·03 G./Oe. Exposure at −80°C. had no effect on permeability.

* 4 hours at 950°C., furnace-cooled to 880°C., oil-quenched, 5 hours at 530°C., air-cooled.

CONSTRUCTIONAL STEELS

Cast Steel with Special Magnetic Properties

H. LÜLING and K. GUT: 'Cast Steel with Special Magnetic Properties.'

Proc. 28th International Foundry Congress, Vienna, 1961, pp. 355–64.

The work reported by the authors was undertaken to examine the feasibility of developing a cast steel, suitable for use in electrical and electromagnetic equipment employed in the power-generating field, which would combine optimum magnetic properties with increased yield strength. Particular attention was paid to the effects of alloying additions and heat-treatment.

The investigation is reported in two sections. The first is concerned with data obtained in determining the effects, on the magnetic properties of pure iron, of small amounts (as encountered in selected scrap) of carbon, silicon, chromium and nickel, and in establishing the variation in magnetic and mechanical properties exhibited by specimens taken from different locations in a low-carbon steel.

In the second section the authors report the results of experiments conducted in an attempt to obtain a cast steel of increased yield strength and high saturation induction. The influence of carbon, manganese, chromium, molybdenum and copper was studied in this respect, and, in tests on 2 per cent. nickel steels, due consideration was given to the ferrite-strengthening effects of nickel. Molybdenum-boron and molybdenum-vanadium steels were also included within the scope of the study.

The data obtained are regarded as illustrating the feasibility of producing steel castings of large cross-section with consistently good mechanical and magnetic properties throughout the casting.

For applications demanding the highest possible saturation induction, components should be cast in iron of the highest purity. Carbon content should be maintained as low as possible, but other impurities (as present in scrap) are shown to have a negligible effect on induction values.

If account has to be taken of yield strength as well as magnetic induction, requirements can, within limits, be met by the carbon steels already available. With alloying additions (such as manganese, chromium and molybdenum) which favour martensite-bainite transformation or pearlite formation, the increase in yield point is associated with a fall in magnetic induction.

The data show that strengthening of the ferritic matrix with nickel or molybdenum/boron additions results in a relatively high yield point (40–45 kg./mm.²) and very good magnetic-induction values (1900 gauss at 300 A./cm.). The nickel steel, production of which is easily controlled, is deemed particularly suitable for large castings.

If yield points are to be as high as possible, use may be made of a precipitation-hardenable steel (e.g., a steel with 0·8 per cent. molybdenum and 0·3 per cent. vanadium).

Glassing Characteristics of Nickel-containing Low-Alloy Steels

G. J. DORMER, G. R. NORTON and B. S. PAYNE: 'Glassing Characteristics of Low-Alloy Steels.'
Jnl. Amer. Ceramic Soc., 1961, vol. 44, Aug., pp. 375–81.

Although glassed-steel* pressure vessels have been used successfully for many years in the chemical and related industries, little information is available on the influence of the basis metal on the performance of the metal/enamel system. With the advent of higher operating temperatures and pressures in the chemical industry, it has become necessary to consider abandoning the currently used steel conforming to A.S.T.M. A 285–57T grade B, in favour of the stronger low-alloy steels, and, in an effort to obtain a better understanding of the effect of metallurgical variables on ceramic-coating behaviour, the authors have carried out tests on various glass/low-alloy-steel composites. The results of this study are reported in the present paper.

The following types of low-alloy steel were selected for evaluation as basis metals: titanium steel; A285–B carbon steel; 'Mayari-R' nickel-chromium steel; A203–A 2½ per cent. nickel steel; A225–A manganese-vanadium steel; A203–D 3½ per cent. nickel steel.

Glass-coated specimens were subjected to:

(1) *Thermal-shock tests*

(2) *Stress-temperature tests*

Using a controlled rate of heating of 14F.° (8C.°) per minute, the specimen was heated to approximately 1100°F. (595°C.), and the thermally-induced deflexion of the glassed test piece during heating was recorded as a function of temperature: the deflexion values were converted to stress values and a stress-temperature plot was obtained for the composite. Maximum compressive- and tensile-stress values, and the temperatures of maximum tension and no-strain, were determined for each metal investigated.

(3) *Thermal-expansion tests*

The maximum temperature used was sufficiently high to ensure that the specimens underwent complete ferrite – to – austenite transformation during heating, and austenite-to-ferrite transformation during cooling. A uniform heating and cooling rate of 900F.° (500C.°) per hour was employed, and the Ac_1, Ac_3, Ar_3 and Ar_1 temperatures were determined.

(4) *Hardenability evaluation*

The hardenability of the steel was determined on the basis of its chemical composition, and, in the present study, the concept of hardenability was extended to cover the relationship between chemical composition and glassing characteristics.

The authors' assessment of the test data derived in the study leads them to conclusions which they summarize as follows:

'(1) Increasing the residual stress in a glass coating tends to increase its resistance to thermal shock. There can be exceptions, however, to this rule.

'(2) The thermal-shock resistance of a glass-metal composite increases with an increase in the transformation temperature of the base metal (Ar_1).

'(3) In a glass-metal composite the residual stress in the glass increases as the transformation temperature of the base metal increases.

'(4) It has been demonstrated that D_I, a concept originally developed for use in calculating the hardenability of alloy steels, has a good correlation with the transformation temperatures of low-alloy steels and may be safely used as an indication thereof in glassing.

'(5) The thermal-shock resistance of a glass-metal composite is reduced with increasing D_I.

'(6) The residual compressive stress of a glass-metal composite decreases with increasing D_I.

'(7) The relation among metallurgical and ceramic properties is useful in making a fairly accurate prediction of the behaviour of a glass-metal composite.'

Formula for Prediction of Susceptibility to Heat-Affected-Zone Cracking in Steels

K. WINTERTON: 'Weldability Prediction from Steel Composition to Avoid Heat-Affected-Zone Cracking.'
Welding Jnl., 1961, vol. 40, June, pp. 253s–8s.

The welding characteristics of a steel are determined by such complex factors that a method of predicting weldability on the basis of composition is unlikely to be forthcoming. If the scope of the term 'weldability' is, however, restricted to the single aspect of heat-affected-zone cracking, the prospects of predicting behaviour from composition are better, since one of the factors controlling cracking is hardenability, which itself depends on composition. The author of the present paper, while emphasizing the dangers of uncritical use of formulae to predict the weldability of steel, suggests that they may be of value in: (1) predicting the behaviour of a new and unknown steel in cases where time or money is not available for proper assessment of weldability; (2) assessing the effect of varying composition within prescribed limits; (3) as a guide in the development of new and experimental steels. The several formulae already available for prediction of weldability in steels give rise to widely differing results, and, after reviewing these formulae and

* The term "glassed steel" is used in connexion with thicker basis metals (approximately ¼ in. (1·25 cm.) thick or more) and heavier glass coatings (approximately 0·06 in. (1·5 mm.) thick) than are usually considered when referring to porcelain-enamelled steel. The basis steel also has a much higher yield strength than grey cast iron, and the glass coating has good resistance to thermal shock and to strong corrosives at elevated temperatures, and does not contain toxic ingredients that can be leached out into the product.

accounting for some of the difference between them, the author therefore advances a new formula which he hopes will provide a sounder basis for such calculations.

The formula, which is based on the relationship between heat-affected-zone cracking and end-of-transformation temperature (M_f) in the austenite/martensite transformation, and enables calculation of equivalent carbon content (C.E.), is given below:

$$C.E. = C\% + \frac{Mn,\%}{6} + \frac{Ni,\%}{20} + \frac{Cr,\%}{10} - \frac{Mo,\%}{50} - \frac{V,\%}{10} + \frac{Cu,\%}{40}$$

Carbon equivalents calculated from the formula appear to correlate reasonably well with data available in the literature on heat-affected-zone cracking and also with new weldability data presented for a group of high-strength steels including 'HY-80'.

The paper includes a table in which carbon equivalents are correlated with the precautions necessary for avoidance of heat-affected-zone cracking.

Influence of Welding Variables on the Yield Strength of Low-Alloy-Steel Weld Metal

W. L. WILCOX and H. C. CAMPBELL: 'Yield Strength of E 9018 Weld Metal.'

Welding Jnl., 1961, vol. 40, May, pp. 193s-6s.

Yield-strength values for as-welded E 9018 weld metal obtained by the manufacturer in certifying a specific lot of electrodes have differed by as much as 20,000 p.s.i. (9 t.s.i.: 14 kg./mm.^{2}) from those derived in tests run by the user in accepting the electrodes. Since it is recognized that the properties of weld metal (particularly low-alloy-steel weld metal) can vary with variations in welding conditions and procedures, the test programme reported by the authors was undertaken in an attempt to establish the degree to which the yield strength of E 9018 weld metal would be influenced by welding variables within the ranges currently encountered in electrode testing and subsequent fabrication.

T steel was selected as the basis metal. Eight test plates were welded with two different brands of $\frac{5}{32}$-in. (4-mm.) E 9018 electrode, using procedures employed in actual submarine-hull construction, or those permitted for lot-inspection tests of electrodes, as required by Specification MIL-E-19322A (SHIPS) for quality-assurance purposes. The percentage composition of the two lots of electrode is given below:

	Lot 1	Lot 2
C	0·046	0·05
Mn	0·88	0·96
Si	0·37	0·3
S	0·015	0·012
P	0·018	0·013
Cr	0·12	0·12
Ni	2·16	1·67
Mo	0·37	0·29
V	—	0·01

All the electrodes were used without rebaking. The weld metal was subjected to mechanical tests in both the as-welded and heat-treated conditions. The results of the test programme demonstrate that the strength of a welded joint depends, *inter alia*, on the specific manner in which the weld metal is actually deposited in the joint, and that an electrode classified as E 9018 in accordance with the provisions of existing specifications may, depending on how the electrode is applied, deposit weld metal exhibiting tensile properties in the as-welded condition characteristic of an E9018, E10018 or, possibly, even an E11018 electrode. Highest-strength weld metal was achieved by use of stringer-bead techniques and low preheat and interpass temperatures.

Welding of '300M' Steel Sheet for Missile Motor Cases

J. F. RUDY, J. I. FISHER, J. P. SHEEHAN, F. SUYAMA and H. SCHWARTZBART: 'Welding of an Ultra-High-Strength Steel for Missile Motor Cases.'

Welding Jnl., 1961, vol. 40, June, pp. 241s.-52s.

The development of solid-propellant missiles has led to a search for pressure-vessel materials exhibiting ultra-high strength in combination with low weight. Various types of material of construction have been considered for use in this connexion, including titanium alloys, hot die tool steels, precipitation-hardenable stainless steels, and low-alloy high-strength steels. '300M'*, essentially a high-silicon modification of the A.I.S.I. 4340 grade designed to exhibit an ultimate strength in the range 280-300 k.s.i., and a yield strength of approximately 230 k.s.i., falls within the last classification. The comprehensive research programme reported by the authors was undertaken in connexion with the use of '300M' sheet for missile motor cases and was intended to throw light on 'weldability', a term which covered both welding procedures and the fabrication variables (thermal and mechanical) influencing the final properties of the welded specimen.

Sheet specimens (0·08-0·125 in. (2-3·125 mm.) thick and differing in geometry) were prepared by gas tungsten-arc welding. Welding procedures are recorded and discussed.

The mechanical behaviour of the weldments was evaluated under uniaxial loading (both transverse and parallel to the direction of welding) and biaxial loading, after application of the standard heat-treatment and special treatments (e.g., modifications of the standard heat-treatment, intentional surface decarburization, and cold rolling) designed to enhance properties. The data obtained are discussed in sections relating to the effects of 'normal good heat-treatment practice', the deleterious effects of particular deviations from this practice, and the improvements in weldment properties which can be obtained by mechanical and/or thermal treatments. It is shown that it is possible considerably to enhance the ability of the specimens to strain prior to fracture (particularly those containing flaws) while maintaining satisfactory engineering strengths.

Of interest in relation to the present paper are two papers (covering, respectively, the influence of melting method on the properties of '300M' and

* Nominal composition: carbon 0·4, manganese 0·75, silicon 1·5, nickel 2, chromium 1, molybdenum 0·4, per cent.

the properties of the steel in sheet form) abstracted in *Nickel Bulletin*, 1961, vol. 34, No. 2, pp. 35 and 36.

Properties of 9 per cent. Nickel Steel in Heavy Sections

D. HARDWICK: 'Some Properties of Steels Containing Nine Per Cent. Nickel.'

Iron and Steel, 1961, vol. 34, Sept., pp. 414–20.

Though extensive data are available on the properties of 9 per cent. nickel steel in plate form, little information has been published on its use in heavier sections as forgings. In this article, the characteristics of 9 per cent. nickel steel are briefly reviewed and rationalized in terms of the mechanism thought to be operative during its heat-treatment. Some unpublished data obtained on large-section forged bar are presented, and the problems likely to be encountered in using the steel in massive section are discussed.

This article is in three sections:

I. In the first, the author reviews data available on the mechanical properties of the steel, commenting on the beneficial influence of nickel on low-temperature impact properties, and drawing attention to the relationship between optimum sub-zero properties and tempering temperatures and times. It is suggested that the excellent impact properties exhibited by the steel are governed by the formation, during tempering, of an optimum amount of stable austenite.

II. It might be expected that an increase in section size could, by its influence on cooling rates and soaking times during heat-treatment, have an adverse effect on the impact properties of the steel. Most of the available data have been obtained on plate less than 2 in. (5 cm.) thick, and little information has been published on the properties to be expected in much larger section sizes. To supplement the sparse data, an upset disc 16 in. (40 cm.) in diameter and 2 in. (5 cm.) thick, $\frac{5}{8}$-in. (16-mm.) gothic bar, and a 9-in. (22·5-cm.) diameter billet were prepared from a 1-ton cast of steel of the following composition, and tensile and impact tests were carried out at sub-zero and room temperature: carbon 0·11, manganese 0·59, silicon 0·21, sulphur 0·007, phosphorus 0·013, nickel 9·28, per cent., aluminium 2 lb. per ton added. Notched and unnotched Wöhler-type fatigue tests were carried out on longitudinal specimens cut from positions towards the surface of the 9-in.-diameter billet. This test programme forms the subject of the second section of the article.

III. To prevent high internal stresses after heat-treatment, large forgings have to be cooled very slowly from tempering temperature, in some cases as slowly as 10C.°/hour. Since in 'conventional' alloy steels this treatment results in temper embrittlement, with an associated rise in transition temperatures and deterioration in low-temperature impact properties, the author undertook the study described in the concluding section of the article to investigate the possibility that 9 per cent. nickel steel might be subject to the same effect. A 28-lb. cast was made to the standard 9 per cent. nickel composition, and, since it was suspected that carbon might influence any tendency towards embrittlement, one cast of lower (0·04 per cent.) and two of higher (0·15 and 0·22 per cent.) carbon were included in the series. Specimens from $\frac{5}{8}$-in. gothic bar tempered within the range room temperature to 600°C. for 4 hours and then water-quenched, or tempered for 4 hours in the range 400°–600°C. and cooled at 10C.°/hour, were subjected to impact tests at room temperature and −196°C., and to tensile tests at room temperature.

The author's detailed discussion of the data derived from the test programme leads him to make the following general comments:

'It is now well established that good and reproducible impact properties at sub-zero temperatures can be obtained in the 9 per cent. nickel composition in plate form. It is still not clear, however, exactly why such properties should be obtained, for, although the presence of stable austenite appears to be necessary, the mechanism by which it exerts its effect is not certain. Further work is required to determine, for example, whether the effect of the austenite is to remove embrittling carbides from the matrix, to reduce the ferrite grain-size, or simply to act as a barrier to the passage of a brittle crack from grain to grain.

'It would seem that lower sub-zero impact properties are to be expected in massive section than in plate, for, in addition to slight deterioration in properties due to reduced cooling rates from austenitizing temperature, the presence of an embrittlement trough in this composition leads to further reduction in impact values on slow cooling from tempering temperature.

'The nature of the embrittlement in 9 per cent. nickel steel is an interesting subject for further study. It has some of the characteristics of temper embrittlement, but it may also be associated with 350°C. embrittlement and carbide precipitation. A clearer understanding of the phenomenon may be obtained when the results of combined isothermal-embrittlement and electron-microscopical studies now in hand become available.'

HEAT- AND CORROSION-RESISTING MATERIALS

Kinetics of Oxygen Adsorption on Nickel and an Iron-Nickel-Chromium Alloy

C. WEISSMANTEL, K. SCHWABE and G. HECHT: 'Kinetics of Oxygen Adsorption on Evaporated Iron, Nickel, Platinum and Alloy Films.'

Werkstoffe u. Korrosion, 1961, vol. 12, June, pp. 353–9.

In the investigation reported, the authors measured manometrically the rate of adsorption of oxygen

(in the range 25°–400°C.) on 500Å-thick vacuum-evaporated films of iron, nickel, platinum and an iron-nickel-chromium alloy. A study was also made of the effects of introducing water vapour into the test environment. The rate of exchange between combined oxygen and oxygen in the gaseous phase was examined by means of a mass spectrometer.

It was not found possible to present the kinetics of oxygen adsorption over the whole of the range studied in terms of any of the known time laws. The sorption rate determined for nickel and platinum was much slower than that for iron, even at the beginning of the process.

The authors also report the findings of experiments in which the corrosion behaviour of the various films was studied by metallographic examination during exposure for several months to atmospheres of dry or wet air.

Influence of Silicon Additions on Oxide Films Formed on Nickel-containing Heat-Resisting Materials

M. SUGIYAMA and T. NAKAYAMA: 'Effect of Silicon on High-Temperature Oxide Films in Heat-Resisting Alloys.'

Nippon Kinzoku Gakkai-si, 1960, vol. 24, No. 8, pp. 541–4.

Using the transmission-electron diffraction technique, the authors studied the initial oxide films formed on the following silicon-containing heat-resisting materials during oxidation in air in the range 700°–900°C.: A.I.S.I. Type 302B chromium-nickel stainless steel (2·45 per cent. silicon); '19-9DL' stainless steel (0·5 per cent. silicon); the iron-nickel-chromium-base alloy 'Durimet 20' (1·27 per cent. silicon); the nickel-chromium alloy 'Nichrome' (approximately 1·5 per cent. silicon).

Electron-diffraction patterns obtained from the initial oxide films after they had been isolated from the alloys revealed the existence of oxides of rhombohedral (mainly Cr_2O_3 or α-$(Cr,Fe)_2O_3$) and spinel type, but no special oxides such as SiO_2. When the films were heated for 1–3 hours at 1200°C., however, α-cristobalite crystals were detected, and the authors conclude that heat-resisting films of amorphous SiO_2 are formed on the materials during the earliest stage of oxidation.

Study of the Titanium-Nickel System between Ti_2Ni and TiNi

See abstract on p. 249.

Melting of Nickel-base Alloys

See abstract on p. 239.

Properties of Dispersion-Strengthened Materials

K. M. ZWILSKY and N. J. GRANT: 'Metal-Metal Oxide Composites for High-Temperature Use.'

Metal Progress, 1961, vol. 80, Aug., pp. 108–11, 122, 124.

In recent years the dispersion-strengthening technique has been applied to the production of materials with improved mechanical properties at room temperature and elevated temperatures. Dispersion strengthening consists of dispersing a finely divided refractory throughout a metallic matrix (generally by powder-metallurgical means) followed by deformation of the composite (usually by extrusion). The finely dispersed phase confers on the composite material very high creep-resistance and structural stability at high temperatures, and, since the metallic constituent remains as the continuous phase, properties such as ductility and workability remain metallic in character. In this review the authors consider the properties and applications of dispersion-strengthened materials.

After alluding to the aluminium/alumina system, in which the potential of the dispersion-strengthening mechanism was first realized, the authors discuss the advantages and limitations of the two methods (mechanical mixing and internal oxidation) employed to disperse the second phase throughout a metallic matrix, and present data (particularly creep-rupture data) typifying the results obtained in applying the dispersion-strengthening technique to copper, nickel and nickel-base alloys, and molybdenum. The potential applications of dispersion-hardened materials are discussed.

Condensing Heat-Transfer Rates of Nickel-containing Condenser-Tube Materials

R. M. JACKSON: 'Condensing Heat Transfer Rates of Tubes of Various Materials.'

U.S. Naval Engineering Experiment Station, Report 030038, July 12, 1956; 20 pp.

The test programme reported was undertaken to determine whether the demand for a reduction in the weight and space of naval propulsion condensers could be satisfied by using higher tube-water velocities to reduce the water-side resistance to heat transfer, and to obtain higher overall heat-transfer coefficients. The current U.S. Navy specifications limiting this velocity to 9 ft./second (2·7 m./second) are based on information on the corrosion-erosion properties of the cupro-nickel alloys currently in use. The purpose of the investigation was therefore to obtain comparative data on the condensing heat-transfer rates of other tube materials exhibiting superior corrosion-erosion resistance at higher water velocities. Titanium, 'Hastelloy C' and duplex tubes were given particular attention.

The following tube materials were selected for study: Admiralty brass, 90–10 cupro-nickel, 70–30 cupro-nickel, 'Hastelloy C', titanium, titanium/90–10 cupro-nickel, 'Hastelloy C'/90–10 cupro-nickel. In the two duplex tubes the cupro-nickel

constituents formed the outer jacket. The outer diameter of all the tubes was nominally $\frac{5}{8}$ in. (1·5 cm.).

The heat-transfer tests were conducted in a single-tube calorimeter incorporated in a test assembly consisting primarily of an evaporator, calorimeter and a 300-sq.-ft. auxiliary condenser. For each tube, several readings were taken at tube-water velocities ranging from 5 to 25 ft./second (1·5–7·5 m./second). The data obtained are tabulated, and curves are presented for the over-all heat-transfer coefficient 'U'. The relative values of U, based on outside tube condensing surface, are recorded graphically as a function of the various velocities studied.

The results of the test programme indicate that, of the materials in common use, 90–10 cupro-nickel offers (subject to the corrosion-erosion characteristics of the material) the best prospect of obtaining a reduction in weight and space by increasing the water velocity. Of the newer materials, the data suggest that titanium promises the greatest advantages with respect to heat transfer. The investigation also indicates that the plain 'Hastelloy C' tubes and the duplex tubes will give heat-transfer rates at least equal to those obtained from 70–30 cupro-nickel, though variations in the quality of mill work, as well as differences in thermal expansion, may render the performance of those of duplex type unreliable.

It is emphasized that calorimeter-test data give higher heat-transfer coefficients than those currently employed in condenser design, and that suitable factors based on actual condenser service conditions must be applied in using the test results for design purposes. The results are, however, regarded as indicative of the relative condensing heat-transfer rates to be expected from the various types of tube studied.

Study of Notch Sensitivity in 'A-286' Steel

G. B. HEYDT: 'Investigation of Notch Sensitivity in 'A-286' Alloy.'

Trans. Amer. Soc. Metals, 1961, vol. 54, June, pp. 220–6.

Specifications for 'A-286' (an age-hardenable iron-nickel-chromium base austenitic alloy used primarily for jet-engine components operating at temperatures up to about 1300°F. (705°C.)) require the alloy to be notch-ductile in a stress-rupture test conducted on a combination smooth and notch test specimen. Notch sensitivity has, however, been encountered even when the composition and microstructure of the alloy have appeared to be normal. The present investigation was undertaken to determine the micro-constituent responsible for this notch sensitivity. Data on notch-ductile and notch-brittle heats of 'A-286' were obtained using light and electron microscopy, reflection electron diffraction, and X-ray techniques.

Based upon observation of notch-ductile and notch-brittle heats over several years of commercial manufacture, three 12½-ton arc-melted heats were chosen as representative of the phenomena to be studied. Stress-rupture tests were conducted on specimens subjected to solution-treatment for 1 hour at 1800°F. (980°C.), oil quenched, aged for 16 hours at 1325°F. (717°C.), and air cooled. Stress-rupture tests were carried out at 1200°F. (650°C.), at a constant stress of 65,000 p.s.i. The first heat, which was used as a control, had a 'normal' structure, and exhibited good stress-rupture properties. The second contained a well-developed cellular precipitate which was visible under the light microscope; it nevertheless exhibited good stress-rupture properties. The third heat contained no cellular precipitate or any detrimental microstructures visible under the light microscope. This heat was notch-sensitive, and broke at the notch in 2·2 hours.

The author's consideration of the results of the stress-rupture tests and the microstructural study leads him to conclude that the presence of a well-developed cellular precipitate visible under the light microscope (identified as Ni_3Ti) is not the cause of notch sensitivity in 'A-286', and that a fine cellular precipitate observable only by means of the electron microscope appears to be the responsible micro-constituent. It has not been positively determined whether this cellular precipitate is Ni_3Ti or some other precipitate such as $M_{23}C_6$.

Tensile Properties of '17-7 P.H.' under Rapid-Heating Conditions

C. R. MANNING and H. L. PRICE: 'Tensile Properties of '17-7 P.H.' and '12 MoV' Stainless-Steel Sheet under Rapid-Heating and Constant-Temperature Conditions.'

Nat. Aeronautics and Space Administration, Tech. Note D-823, May 1961 ; 28 pp.

Aerodynamic heating of missiles and re-entry vehicles has led to considerable research on the effects of rapid heating on the tensile strength of relevant materials. Previous investigations had shown that the tensile strength depends upon the temperature rate, and is greater when the material is heated rapidly than when it is heated under conventional constant-temperature conditions. In the work now reported, '17-7 P.H.' and '12MoV' stainless-steel sheet specimens were heated to failure at temperature rates ranging from about 1F.° to 170F.° (0·5C.° to 95C.°) per second under constant tensile-load conditions. The results of these tests are compared with data derived from short-time elevated-temperature tensile tests carried out in previous studies. Master curves, based on a rate-temperature parameter, are presented for the yield and rupture stresses obtained under rapid-heating conditions.

The test data show that, depending upon the stress, temperature, and temperature rate, yield and rupture stresses may be greater or less than the corresponding yield or tensile strength obtained from the conventional stress-strain test. For the most part, the yield and rupture temperatures for the two materials increased with the logarithm of the temperature rate. The yield and rupture temperatures calculated from master curves obtained by applying

the Larson-Miller form of the rate-temperature parameter to rapid-heating data for the two steels showed good agreement with the experimental results.

From the close agreement between strain measurements taken by the optical strain-measuring system employed in the study and those obtained by means of the extensometer strain-measuring system, it is concluded that the former technique can be successfully used in rapid-heating tests.

Structure and Properties of a Copper-Nickel-Silicon Age-Hardenable Alloy

See abstract on p. 249.

Explosive Forming of Nickel-containing Materials

In explosive forming, one of the most dramatic of the new metal-working techniques, the material is formed not with a punch or diaphragm as in a conventional machine, but by means of an explosive charge which, though very small, is capable of exerting treme ndous forces. Since the explosive forces are so large, and detonation pressures develop so rapidly, the forming rate is usually in the range 250–500 ft./sec. (75–150 m./sec.), and the peculiar advantages and disadvantages of the process are associated with these extremely high forces and forming rates.

The uses, advantages and limitations of explosive forming are discussed in the four papers referred to below. The first refers to work by Rocketdyne Division of North American Aviation, Inc., and includes photographs of components explosive-formed from tantalum, aluminium, 'P.H. 15-7 Mo', and various grades of chromium-nickel austenitic steel. The second, which is based on experience gained by Ryan Aeronautical Company in explosive forming complex shapes and in producing parts to close tolerances, is illustrated by photographs of components formed from aluminium, 'K Monel', 'Hastelloy X', 18-8 stainless-steel and 'A-286'. The third article draws attention to the advantages which explosive forming offers in the fabrication of such conventional materials as re-sulphurized steels, and the authors of the last paper (who are with the Boeing Company) allude to progress with a forming process which, using mixtures of hydrogen, oxygen and an inert gas, is stated to possess the advantages of conventional explosive forming while eliminating some of its defects.

V. H. MONTEIL: 'How to Design for Explosive Forming.'
Metal Progress, 1961, vol. 80, Aug., pp. 66–70.

F. A. COX: 'Ryan's Experience in Explosive Forming.'
Ibid., pp. 71–3.

R. G. MONSEES: 'Steel Parts Formed on High-Energy-Rate Machine.'
Ibid., pp. 74–5.

J. MILLER and P. KRUSE: 'Explosive Forming with Combustible Gas Mixtures.'
Ibid., pp. 76–8.

Forgings in High-Temperature Alloys

H. J. HENNING and F. W. BOULGER: 'Superalloy Forgings.'
Defense Metals Information Center, Battelle Memorial Inst., Memorandum 86, Feb. 10, 1961; 41 pp.

Many of the forgeable 'superalloys' developed to meet the severe requirements of the aeronautical industry are in the transition stage between development and full-scale production. This memorandum was compiled to provide data on forgings in the newer nickel-base, iron-base and cobalt-base high-temperature alloys suitable for service in the range 1200°–1800°F. (650°–980°C.). The information collated was obtained from publications, and from a survey of alloy producers, forging companies, and consumers.

The memorandum is in five sections. In the first section, the authors tabulate the compositions of materials falling within the three classes of forgeable alloy discussed, and briefly consider the effects of melting practice on properties. Forging practices are commented upon in the next section, and, in this connexion, reference is made to side forging and die forging and the factors involved, and precautions necessary, in heating such alloys for forging. Recommended forging temperatures are tabulated for: 'A-286', 'V-57', 'M-308', 'Inco 901', 'Hastelloy R-235', 'Haynes Alloy 25', 'Waspaloy', 'M-252', 'D-979', 'U-500', 'Inco 700', 'René 41', 'U-700', 'Astroloy'.

The survey indicated that turbojet-engine components (such as turbine discs, hubs, blades, and other parts exposed to high temperatures) still form the major application of 'superalloy' forgings. It was also apparent that many of the alloys are employed in air-frame applications, which, although not involving exposure to extremely high temperatures, require materials with adequate oxidation- or corrosion-resistance (engine mounts, arrester hooks and miscellaneous fittings have, for example, been forged from 'A-286', 'René 41', 'Inconel X' and other heat-resisting alloys). Types of forging are commented upon, and typical components are illustrated, in the third section of the memorandum.

The mechanical properties of forgings form the subject of the fourth section of the review, and data are tabulated on the tensile and stress-rupture properties of specimens taken from discs forged from 'Waspaloy', 'U-500', and 'V-57'. Alloys obtainable as forgings with guaranteed properties are listed, and the properties guaranteed for forgings in 'Waspaloy', 'Astroloy', 'U-500' and 'René 41' are given.

A résumé of information submitted by aircraft and missile producers concludes the review.

Surface Coatings for Protection of High-Temperature Alloys during Heat-Treatment

E. L. STONE and L. ALBERTIN: 'Surface Coatings Protect Parts During Heat-Treatment.'

Metal Progress, 1961, vol. 79, June, pp. 103–6, 124, 128, 131A, 131B.

The special facilities available to prevent surface oxidation of steel and heat-resisting alloys during heat-treatment (e.g., molten salt baths, vacuum furnaces) are costly, require rigid process controls and are economically justifiable only when the parts to be treated are produced in sufficiently large quantities. Where production quantities are low, the authors suggest that protective coatings be applied to the components before heat-treatment. Such coatings have been successfully employed by the Boeing Airplane Company for the protection of such parts as 'Hastelloy X' turbine nozzle boxes, Type 321 stainless-steel ducts, and thin sheet materials for airframe skins. The coatings, which decrease metal loss during pickling and facilitate removal of scale, can be classified as scale conditioners, mechanically-bonded protective coatings, and plated and diffusion coatings. In this article the authors discuss experience in the application of the three types of coating to steel and heat-resisting materials.

Two types of scale conditioner have been extensively employed by Boeing: the oxidation-inhibiting coatings consisting of silicone oil or grease, and clay-suspension coatings. The former type was developed for use with stainless steels, but may also be applied to other materials; the latter is used predominantly with nickel- and cobalt-base alloys. Coating and pickling procedures are outlined, and typical descaling times and metal losses for clay-coated 'Réne 41', 'Haynes Stellite 25' and 'Hastelloy X' are tabulated.

Mechanically bonded coatings (of nickel-chromium and nickel-chromium-boron alloys) are discussed in relation to their performance on mild-steel fixtures used to hold titanium alloys during thermal treatment, while the advantages of plated and diffusion coatings are exemplified in terms of the use of a copper coating to protect selected areas on components to be case hardened.

The article includes notes on the use of ceramic coatings and aluminium paint to prevent contamination of titanium alloys and stainless steels during heat-treatment. Reference is also made to the bright annealing of nickel- and cobalt-base high-temperature alloys by heat-treating them in a sealed retort in the presence of ammonium fluoride and chromium or nickel powders. When the parts are treated at an elevated temperature, the ammonium fluoride reacts with the metal powders and is dissociated. A thin fluoride skin of low volatility is formed on the surface, and, at higher temperatures, is reduced to form a reducing atmosphere.

Metallizing of Machinery and Moulds Used in the Glass Industry

J. A. FAWCETT: 'Metallizing of Glass Machinery and Moulds.'

Glass Technology, 1961, vol. 2, Aug., pp. 142–5.

Sprayed metal coatings are employed in the glass industry to rebuild worn parts, to salvage those mismachined, or to provide a suitably wear-resistant surface. In this article the author discusses the materials used in, and the properties obtainable from, coatings deposited by (*a*) the metallizing technique, and (*b*) the 'ThermoSpray' and plasma-flame processes.

In metallizing, the metal to be deposited is employed in wire form. Typical materials available for wire metallizing (e.g., molybdenum, carbon steels, high-chromium and 18–8 stainless steels, 'Monel', nickel) are correlated with coating hardness, and the applications and characteristics of the coatings are briefly discussed.

The term 'ThermoSpray' relates to a flame-spraying technique involving the deposition of metallic and other materials which, before melting and spraying, are in powder form. The use of the process is described in sections concerned with the three types of coating material employed: (1) self-fluxing alloys and tungsten-carbide/alloy materials; (2) oxidation-resisting materials; (3) ceramic materials. The compositions of available 'ThermoSpray' powders are tabulated.

Materials of group (1) are basically chromium-nickel alloys to which boron and silicon fluxing agents have been added. Several alloys have been modified to provide 'ThermoSpray' powders with a wide plastic range, which enable heavy sprayed coatings to be fused without difficulty. Although these alloys melt at approximately 1900°F. (1035°C.), they retain a relatively high degree of hardness at temperatures close to their melting points, a property which, in combination with high resistance to oxidation and erosion, renders them of value for use on mechanical components intended for high-temperature service. They are very resistant to wear and abrasion (and will often out-wear steel of equivalent hardness by a factor of 20–1), and are highly resistant to corrosion and oxidation.

Coatings obtained with powders consisting of high-quality sintered tungsten carbide blended with a self-fluxing alloy exhibit matrix hardnesses in the range Rockwell C60–62 and a carbide hardness of Rockwell C75. These powders are recommended for application where resistance to severe abrasion is required.

Group (2) of the 'ThermoSpray' powders includes two stainless steels and an 80–20 nickel-chromium alloy. The chromium-nickel coatings produced behave very similarly in service to those obtained from the same metals by wire metallizing, and are intended primarily for applications requiring oxidation-resistance. They are not self-fluxing.

Of the many refractory and cermet coatings in group (3) which may be sprayed by the 'ThermoSpray' technique, alumina and zirconia are the most widely used.

The plasma-flame process, notes on which end the article, extends the range of materials that can be deposited by spraying to those whose melting temperatures are above the limits of the oxy-acetylene flame.

Spectroscopic Standard Samples for Nickel-containing High-Temperature Alloys

R. E. MICHAELIS: 'Spectroscopic Standard Samples of Titanium and High-Temperature Alloys.'

Applied Spectroscopy, 1961, vol. 15, No. 1, pp. 7-8.

Ten new spectroscopic standard samples are now available from the National Bureau of Standards, three each for two titanium alloys, and four for the following nickel-containing high-temperature alloys: 16-25-6 (Cr-Ni-Mo), 'Inconel X', 'Waspaloy' and 'Waspaloy' modified.

Details of the ten standard samples, which are stated to be useful for both optical emission and X-ray methods of analysis, are given by the author.

Minimum Temperature Limits of Oil-Ash Corrosion

N. D. PHILLIPS and C. L. WAGONER: 'Use of Differential Thermal Analysis in Exploring Minimum Temperature Limits of Oil-Ash Corrosion.'

Corrosion, 1961, vol. 17, Aug., pp. 396t-9t.

In a previous paper (see abstract in *Nickel Bulletin*, 1961, vol. 34, No. 1, pp. 14-15), the authors investigated oil-ash corrosion using a pilot-scale furnace which enabled materials to be tested under closely controlled conditions of gas temperature, metal temperature, fuel composition, and firing. Since corrosion is associated with the presence of liquid ash, it was necessary to determine the lowest metal temperature at which the ash deposit could exist as a liquid (this temperature is critical for the initiation of corrosion and may vary with the ash composition). The present study of the melting and freezing characteristics of ash deposits was carried out mainly by means of differential thermal analysis, but pilot-plant corrosion tests were also included in the laboratory programme.

During a differential-thermal-analysis study of additive/ash reactions involved in oil-ash corrosion, it was observed that differences occurred between the melting and freezing temperatures of the sodium-vanadate compounds under investigation, the freezing temperatures being significantly lower. Since deposits occurring in boilers are the result of solidification of liquid ash from high-temperature gas streams, knowledge of the presence of liquid material at lower temperatures than indicated by conventional melting-point determinations is important in predicting the occurrence of corrosion and fouling. A laboratory investigation was consequently undertaken to explore this phenomenon more fully. Stoichiometric mixtures of sodium sulphate and vanadium pentoxide were prepared, and their fusion reactions and the resulting sodium-vanadate compounds were studied (melting and solidification data are recorded in the paper). The assumption that the difference between the liquidus temperatures obtained on heating and cooling sodium vanadates is dependent on the oxygen-absorption capacity of liquid ash was also investigated. Other phases of the research were centred on the relationship between deposit composition and fuel composition and between deposit composition and corrosion, and on the inhibitive effects of magnesia additives.

The data presented demonstrate that the solidification temperatures of V_2O_5-Na_2SO_4 reaction products can be as much as 125F°. (70C°.) lower than the melting temperatures. This temperature difference, which is correlated with oxygen absorption of the liquid ash, is considered significant in relation to high-temperature corrosion, due to the fact that corrosion can result from liquid ash present at temperatures lower than those indicated by melting-point determinations (the criteria universally used prior to the present study to define the first appearance of the liquid state).

By means of the D.T.A. technique, a eutectic occurring between the composition of $Na_2O.3V_2O_5$ and $NaVO_3$ was determined which, it was found, can result in measurable corrosion at metal temperatures as low as 895°F. (480°C.), especially in zones of high gas temperature: this temperature represents the minimum metal temperature for the initiation of oil-ash corrosion.

The authors show that the sodium/vanadium value of deposits can differ from that of the fuel, and they present a relationship for this (correlating the deposit value, the fuel value and the gas temperature) which provides a means of estimating the composition of a given boiler deposit.

Use of such additives as magnesium oxide can, it is concluded, reduce corrosion. Materials at a metal temperature of 1200°F. (650°C.) exhibited less metal loss in the presence of an additive than at 1100°F. (595°C.) without an additive.

The chemical reaction between magnesium oxide and vanadium pentoxide at a magnesium/vanadium ratio of 3/1 by weight was found to be complete at 1210°F. (655°C.), and the melting and solidification temperatures of the product were in the region of 2100°F. (1150°C.). When an additive is used at deposit temperatures below the additive/ash reaction temperature, reduction in corrosion is due primarily to mechanical dilution. When metal and deposit temperatures exceed the necessary reaction temperatures, inhibition of corrosion is facilitated by the additive/ash reaction, which gives rise to a high-freezing, non-corrosive product.

Resistance of 'Hastelloy B' to Corrosion by Rubidium at High Temperatures

R. CARLANDER: 'The High-Temperature Corrosion-Resistance of 'Hastelloy B' and Molybdenum to Rubidium.'

U.S. Atomic Energy Commission, Oak Ridge National Laboratory Report 56-8-85, Aug. 14, 1956; 7 pp. Recently de-classified.

Rubidium, having properties which render it suitable for consideration as a nuclear-reactor material, was

proposed as a possible coolant in a high-temperature vapour-cycle power-plant study. The tests summarized in the present report were carried out to determine the suitability of molybdenum and the nickel-molybdenum-iron alloy 'Hastelloy B' for use as materials of construction in contact with the metal.

'Hastelloy B' capsules, filled with rubidium to 20 per cent. of their volume under an inert atmosphere, were subjected to see-saw and standpipe tests, and one see-saw test was carried out on a similar specimen fabricated from molybdenum. The tests, in which the specimens were exposed in some instances to temperatures as high as 1900°F. (1035°C.), and which were carried out for 500 hours, resulted in no mass transfer and little attack. The depth of attack on the 'Hastelloy B' capsules (0·5 to 2 mil) was approximately the same in the bath, boiling and vapour zones. In the standpipe tests, intergranular penetration was observed in the bath and boiling zones, but not in the vapour zones. Attack in the see-saw test was in the form of subsurface voids.

No attack occurred in the see-saw test on molybdenum, but recrystallization occurred in the outer region of the hot zone.

Intercrystalline Penetration of a Nickel Alloy by Liquid Bismuth

R. F. CHENEY, F. G. HOCHGRAF and C. W. SPENCER: 'Penetration of Liquid Bismuth into the Grain Boundaries of a Nickel Alloy.'

Trans. Metallurgical Soc., A.I.M.E., 1961, vol. 221, June, pp. 492–8.

Liquid metal in contact with the surface of an unstrained solid metal will usually penetrate to a certain extent into the grain boundaries of the solid, and many observations of a qualitative nature concerning intercrystalline attack by liquid metals have been reported. In the investigation now recorded, columnar-grained specimens of nickel (containing 0·25 per cent. silicon and 0·22 per cent. manganese) were exposed to liquid bismuth in the range 670°–1050°C. In studying penetration, consideration was given to complications which might arise as a result of plastic strain, boundary migration, the stability of the specimen surface, and the presence of alloys where three grains intersect.

Under isothermal conditions, the liquid penetration rate was found to be constant. The activation energy for the process was 2200 cal. per g-atom. The small amounts of plastic deformation to which specimens were subjected prior to exposure increased the penetration rate. It appeared reasonably certain that the slow step in liquid film penetration is associated with a reaction which occurs at or near the leading edge of the film (either transfer of nickel across the liquid/solid interface, or diffusion in the grain boundary ahead of the liquid film, is suggested).

Fundamental Behaviour of Passive Alloys

H. H. UHLIG: 'Fundamental Behaviour of Passive Alloys.'

Werkstoffe u. Korrosion, 1961, vol. 12, July, pp. 413–16.

In this review of the factors influencing the passivity of alloys, the author bases his conclusions on data culled from the literature. The mechanism of passivation in alloys, alloying additions associated with passivation, the critical composition for passivation, and passivation in multi-phase alloys are among the aspects discussed.

The susceptibility of a basis metal (e.g., iron) to corrosion can, it is shown, be considerably reduced by addition of alloying elements (e.g., chromium) which increase tendency to passivation, either by lowering the current density necessary for passivation to values of the magnitude of the corrosion current, or by shifting the Flade potential to less noble values. A further possibility of achieving passivity lies in the addition of alloying elements which increase the rate of the cathodic reaction, and thus enable the initial corrosion current density to be raised to the critical passivation current density (as, for example, occurs when palladium is added to 18–8 stainless steel or titanium). Multi-phase alloys can in principle be rendered passive in a similar way (i.e., by a local current effect when the cathodic reaction is accelerated).

Data are presented in illustration of the fact that the critical passivation current density reaches a minimum at, and above, a critical alloy composition, e.g., 12 per cent. chromium in the case of chromium-iron alloys, and 30–40 per cent. nickel with nickel-copper alloys. The factors contributing to this effect are discussed.

Flade Potential of Nickel

See abstract on p. 240.

Anodic Polarization of Stainless Steel in Chloride Solutions

G. M. SCHMID and N. HACKERMAN: 'Anodic Polarization of Stainless Steel in Chloride Solutions.'

Jnl. Electrochemical Soc., 1961, vol. 108, Aug., pp. 741–4.

Previous investigations by the authors have shown that a maximum occurs in the potential/time curve during constant-current anodic polarization of stainless steel in Cl^- solutions. In the work described in the present paper, the effect of Cl^- was studied further in experiments in which anodic-polarization curves were determined for Type 302 18–11 chromium-nickel stainless-steel electrodes in KCl solutions up to 1·0*N*. The pH was adjusted by the addition of NaOH or H_2SO_4. The total concentration ordinarily was kept at 1·0*N* by adding the appropriate amount of Na_2SO_4.

The data obtained in the study verify (except at pH 12) the existence, during anodic polarization, of

maxima in the potential/time curve at 0·3*N* Cl^- and above. It is shown that the anodic Tafel slopes obtained in chloride-free 1·0*N* Na_2SO_4 and 0·1–1·0 *N* KCl of pH 1·5, 6 and 12 coincide if the potential maxima are plotted. Measurement of the time necessary for the potential to decay to an arbitrary value of +0·5 v. *vs* SCE revealed it to be dependent on the time at open circuit just before measurement. For less than 3 minutes, it is a function of this time; for more, there is no effect, at least over one order of magnitude of the applied anodic current density.

It is proposed that the first effect of the anodic current is the conversion of an adsorbed sheet of water dipoles into a protective chemisorbed oxygen layer. With time, the chemisorbed oxygen is replaced by chemisorbed Cl^-, which causes a potential decay. It is pointed out that there is no binding reason to assume an oxide film in explanation of the pitting action of Cl^-.

Study of Pitting Corrosion in Austenitic Stainless Steels

E. BRAUNS and W. SCHWENK: 'Study of Pitting Corrosion in Austenitic Corrosion-Resisting Steels.'

Archiv. f. d. Eisenhüttenwesen, 1961, vol. 32, June, pp. 387–96.

In the work reported, the authors studied pitting corrosion of austenitic stainless steels with the aim of gaining information on the type, progress and rate of attack suffered.

The five chromium-nickel stainless steels selected for investigation were of 18-10, 18-10-2Mo, 18-9-0·5Mo-Ti, 17-12-2Mo-Ti, 19-10-Nb and 18-12-2Mo-Nb type. Corrosion behaviour was evaluated by means of various experimental techniques (e.g., by Turnbull's blue colour reaction, metallographic examination, and, in particular, galvanostatic and potentiostatic polarization measurements), and special attention was paid to the influence of chlorine and nitrate ions present in the corrosive media. The results of the experiments (which are presented in detail in the paper) lead the authors to advance a theoretical explanation of the progress of pitting corrosion. The advantages of the various experimental techniques employed in the study are discussed.

The authors conclude that the presence of chlorine ions is necessary not only for the formation of pits but also for the maintenance of the active corrosion condition in the pits. Pitting corrosion can be brought to a standstill if the corrosive medium is subsequently freed from chlorine ions.

Alkaline inhibitors are regarded as satisfactorily effective, but the nitrate inhibitor studied ($NaNO_3$) is, it is stated, usable only in conjunction with an oxidizing medium (adequate aeration), since pitting corrosion can occur unhindered at low potentials. In neutral solutions care must be taken to ensure that the potential of the material remains below the pitting-corrosion potential, by, for example, cathodic protection. Simultaneous application of alkaline inhibitors can be particularly effective, since they shift the pitting-corrosion potential to positive values. Use of cathodic protection in conjunction with nitrate inhibitors would tend to promote rather than inhibit pitting attack.

See also

Study of Pitting Corrosion in Stainless Steels by Turnbull's Blue Colour Reaction

H. STOFFELS and W. SCHWENK: 'Studies of Pitting Corrosion in Corrosion-Resisting Steels by Means of Turnbull's Blue Colour Reaction.'

Werkstoffe u. Korrosion, 1961, vol. 12, Aug., pp. 493–500.

In this paper the authors present and discuss the results obtained in applying hexacyanoferrate III as a redox system in experiments to evaluate the susceptibility of stainless steels to pitting corrosion in chloride-containing solutions. The redox potentials coincide with those which can occur in neutral aerated solutions, and, in addition, the reagent forms an intensely coloured deposit with the products of corrosion (iron II ion), and permits determination of the induction time and the position of the pitting-corrosion potential relative to the test potential.

Data established by means of the technique are presented in the form of diagrams indicating the corrosion-resistance of the following chromium-nickel stainless steels as a function of the concentration of chlorine-ion and inhibitor (sodium nitrate, sodium hydroxide or a pyridine phosphate) present in the test solution: 17 per cent. chromium steel containing titanium or titanium and molybdenum, and chromium-nickel steels of 18-8, 18-8-Ti, 18-8-Nb, 18-8-2Mo, 18-8-2Mo-Ti, 18-8-2Mo-Nb, 18-23-3Mo-Cu-Nb, and 17-14-4Mo type. A curve correlating induction time with chlorine-ion concentration shows the relationship to be of linear-reciprocal type (as is the case with pure iron). On the basis of this relationship, a study was made of the influence of different pre-treatments on specimen behaviour, and, in this connexion, the effects of nitric-acid passivation treatments are discussed. It is shown that nitric-acid treatment has the effect merely of 'cleaning' the metal surface, and therefore permits the formation of a corrosion-resisting film during subsequent contact with air or other passivating medium. Of the passivation pre-treatments studied, exposure to boiling 30 per cent. nitric acid is regarded as the most effective.

Influence of Ageing Temperature on Stress-Corrosion Cracking of '17-4 P.H.'

'Higher Ageing Temperature Prevents Corrosion of '17-4 P.H.'.'

Metal Progress, 1961, vol. 79, June, pp. 8–9.

Modification of the control-rod drives for the Dresden nuclear-power reactor is nearing completion. All of the reactor's eighty control rods and drives, some of which were found last November to have undergone stress-corrosion cracking, have been rebuilt by the General Electric Company, the reactor manufacturer, with replacement materials ('17-4 P.H.'

steel, Type 304 18–8 stainless steel, 'Haynes Alloy 25', and 'Inconel X') selected because of their proven performance in nuclear-reactor water at high temperatures. All the new index tubes and roller mounts are to be fabricated from '17–4 P.H.', but an ageing temperature of 1100°F. (595°C.) will be substituted for that of 900°F. (480°C.) formerly used. The reason for this change is given in this brief note.

In a test programme initiated by the General Electric Company, stressed specimens of '17–4 P.H.' aged at 1100°F. or 900°F. were subjected to autoclave and dynamic loop tests. Only the specimens aged at 900°F. cracked. A complementary series of experiments demonstrated that ageing treatment at 1100°F. reduces high residual stress, and, it was concluded, results in a condition in which the alloy is not susceptible to stress-corrosion cracking. No cases of stress-corrosion cracking in '17–4 P.H.' heat-treated in the range 1050°–1100°F. have occurred, either in laboratory tests or in reactor service in high-temperature water. The U.S. Navy, it is stated, uses '17–4 P.H.' (H1100) in submarine reactors for parts of drive mechanisms corresponding to index tubes in the Dresden reactor.

Susceptibility of 'AM-350' to Stress Corrosion in the Notched Condition

R. T. AULT: 'Stress Corrosion of Notched and Unnotched 'AM-350' Alloy.'

Wright Air Development Division, Tech. Note 60-95, May 1960; 11 pp.

The high-strength steels (yield strength 180,000 p.s.i. and above) are known to be susceptible to stress-corrosion cracking under certain conditions of stress, environment, heat-treatment and specimen configuration. An important consideration in their use, particularly when heat-treated to a high hardness level, is the possibility that assemblies fabricated from such materials may fail by brittle fracture at a small fraction of the design stress. Localized corrosive attack might result in a crack or stress-raiser and terminate in fracture of the metal under the influence of stress. It follows that a steel heat-treated to be notch-sensitive would be expected to rupture as soon as a stress-corrosion crack had grown large enough to become an effective notch, the remainder of the metal failing by brittle mechanical fracture. Conversely, a steel heat-treated to be notch-insensitive under the same conditions would have to undergo considerable stress-corrosion cracking before the stress exceeded the residual strength of the metal. It would be supposed, therefore, that the effect of a mechanically-induced notch or stress raiser would be to accelerate the rate of stress-corrosion cracking. The purpose of the study now reported was to determine the effect of a mechanically induced notch on the susceptibility of the high-strength semi-austenitic stainless steel 'AM-350' to stress-corrosion cracking.

The steel was of the following composition: carbon 0·07, manganese 0·68, silicon 0·24, phosphorus 0·015, sulphur 0·008, chromium 17·89, nickel 4·32, molybdenum 2·7, nitrogen 0·06, per cent. Sixteen tensile specimens, rough-machined from sheet, were heat-treated as follows, and then finish-machined, and ground to a thickness of 0·051 in. (1·275 mm.): annealed for 10 minutes at 1710°F. (930°C.), air cooled, refrigerated for 3 hours at −100°F. (−75°C.), tempered for 3 hours at 850°F. (455°C.), and air cooled. Eight of these specimens were notched, and eight unnotched, and four specimens in both groups were taken transverse, and four longitudinal, to the rolling direction. Alternate-immersion-type stress-corrosion tests were run, in 3½ per cent. sodium-chloride solution, on specimens loaded to 60 per cent. of the 0·2 per cent. offset yield strength.

All of the unnotched specimens failed within 150 hours, while none of the notched had failed after 800 hours of testing. The data are regarded as indicating the high susceptibility of 'AM-350', in the RH-850 condition, to stress-corrosion cracking in a sodium-chloride environment. The results suggest that the stress level does not play an important rôle in this connexion. Stress raisers, such as holes, notches, threads, etc., do not therefore significantly influence the susceptibility of a material to stress-corrosion cracking. A more important factor is deemed to be the presence, on the surface of the metal, of micro inhomogeneities which enhance the likelihood of localized attack by the corrosive environment. This finding does not mean that the overall stress state of the material is not influential in the propagation phase of stress-corrosion cracking.

Symposium on Handling of Acid Slurries

The Canadian Mining and Metallurgical Bulletin, 1961, vol. 54, May, contains the texts of seven papers presented at a Symposium on Slurries held during the 1960 Annual General Meeting of the Canadian Institute of Mining and Metallurgy at Toronto. The first paper is concerned with the general aspects of the problem, and is intended to serve as an introduction to the information on specific processes presented in the other six. In these six papers the difficulties encountered in handling slurries under particular operating conditions are discussed, and reference is made to corrosion experience and to the materials of construction which have been found suitable for such service.

The scope of the various papers is briefly indicated in the abstracts below.

F. L. LAQUE: 'Factors in Deterioration of Metals by Acid Slurries', pp. 361–6.

In this introductory paper the author considers some of the basic factors involved in the corrosion of metals by acid slurries, and, by way of illustrating their significance, alludes to information on the ways in which the following variables influence the behaviour of steel, iron, lead, chromium-nickel austenitic stainless steels, and titanium in acid slurries:

the nature and concentration of the acid involved; the effects of constituents taken into solution by the acid; temperature; turbulence; abrasion by suspended particles; the shielding effects of adherent solids. Sulphuric acid, since it is the most common acid encountered in slurries, is selected for discussion as the main corrosive medium.

R. R. HOFFMAN and R. J. TREMBLAY: 'Acid Pulp Handling at Eldorado's Port Radium Operation', pp. 367-72.

The Port Radium Mill of Eldorado Mining and Refining, Limited, was the first uranium acid mill to be brought into production in Canada. This paper outlines the problems encountered and overcome in leaching and filtering an oxidized sulphuric-acid slurry during its first eight years of operation.

The slurry is characterized by a high calcium-sulphate content and a high chloride level under oxidized conditions, both of which factors affected the initial design of the plant and subsequent changes.

Details are given of the materials of construction employed for plant equipment. The leach agitation tanks are of wood, with a mild-steel superstructure, while the agitator and all moving parts below solution level are in stainless steel (mainly Type 316 17-12-Mo steel). The temperature of the slurry is controlled by electropolished Type 316 stainless-steel cooling coils. The string filters are of Oliver type with wood decking. Extensive use is made of wood, 'Linatex'-lined mild steel, and stainless steel in handling the slurry.

J. B. MITCHELL and A. G. ROACH: 'Handling of Acid Slurries at Algom Nordic', pp 373-80.

The authors' aim is to 'outline some of the slurry-handling methods employed in uranium mills, and to point out some of the difficulties encountered'. The information presented is based on experience obtained in operating the Nordic Mill of Algom Uranium Mines, Limited, which treats about 3,400 tons of uranium-bearing pebble conglomerates per day. Sulphuric acid is employed as the leaching reagent.

The authors discuss the factors which influenced selection of the materials used in building construction, floors and sumps, pumps, valves, launders, mechanical agitators, pachucas and filters, and the paper includes brief notes on the suitability of stainless steels and rubber-lined materials for such service.

S. S. FORBES: 'Handling of Anode Slime at Canadian Copper Refiners Limited', pp. 381-2.

The author gives details of the treatment employed by Canadian Copper Refiners, Limited, for recovery of copper, silver, gold, selenium and tellurium from anode slime, and refers to the materials of construction which experience has shown to give satisfactory service under the operating conditions.

R. B. MCINTOSH and S. ROMANCHUK: 'Corrosion Experiences in the Acid Leaching of Cobalt-Nickel Sulphides', pp 383-8.

Since 1954, the ammonia leach process has been employed by Sherritt Gordon Mines, Limited, to recover nickel metal, copper sulphides, and cobalt-nickel sulphides from nickel concentrate produced at Lynn Lake, Manitoba. To develop a process for recovery of cobalt and nickel from the cobalt-nickel sulphides, laboratory and pilot-plant studies were carried out, and late in 1957 the refinery commenced continuous acid leaching of sulphides. In September 1958, the present equipment and operating procedures were finalized. In this paper, the authors give a brief outline of the process employed for treatment of nickel concentrates, and a detailed description of the sulphide leaching process, and then present the results of corrosion tests performed to determine materials suitable for use in plant employed in the sulphuric-acid leaching of nickel-cobalt sulphide slurry at a pressure of 100 p.s.i.g. and a temperature of 250°F. (120°C.).

Corrosion spools containing specimens of the following materials were installed below the solution level in the first and third compartments of the leaching autoclave: stainless steels of 18-10, low-carbon 18-9, 17-11-2Mo, low-carbon 18-13-2Mo, welded 18-12-3Mo, 18-14-3Mo, low-carbon 18-14-3Mo, and 18-11-Nb type (i.e., A.I.S.I. Types 304, 304L, 316, 316L, welded 317, 317, 317L, and 347); 'Carpenter 20Cb'; 'Ni-o-Nel'; titanium; lead. Some non-metallic specimens were tested in the third compartment. After 72 days the specimens were removed from the autoclave and corrosion rates were calculated.

The data presented indicate that Types 304, 304L and 347 steels are unsuitable for plant service. The molybdenum-containing grades Types 316 and 317, however, exhibited much higher corrosion-resistance. Little difference was observed between the performance of 'Carpenter 20Cb' and 'Ni-o-Nel', their corrosion-resistance being somewhat better than that of Type 316 steel and nearly the same as that of Type 317. Titanium was completely resistant to attack, while lead was entirely dissolved in both compartments.

The materials at present in use in plant equipment are discussed, and it is stated that Type 316L steel is giving fairly satisfactory service. It is anticipated that Type 317 steel, 'Carpenter 20Cb' and 'Ni-o-Nel' would offer somewhat better performance, and that titanium would be virtually immune to attack.

J. N. LILLEY, R. W. CHAMBERS and C. E. YOUNG: 'Handling of Acid Slurries at the Flash Smelting Plant of The International Nickel Company of Canada, Limited', pp. 389-91.

In recovering nickel, copper, iron ore and other elements from Sudbury ores, The International Nickel Company of Canada, Limited, separates the valuable constituents into three concentrates,

in which copper, nickel, and iron predominate, respectively. The high-grade chalcopyrite concentrate is reduced to blister copper by oxygen flash smelting and Bessemerizing. The flash-smelting process involves injecting the copper concentrate, together with fluxes, in a stream of 95 per cent. pure oxygen, into a specially designed furnace. The resulting autogenous smelting reactions produce a high-copper furnace matte, an iron-silicate slag, and a flue gas, containing over 75 per cent. SO_2, used for production of liquid sulphur dioxide. Before delivery to the liquefaction plant, the furnace gas is cooled and scrubbed to remove dust particles. The gas-cleaning system cools the gas to 95°F. (35°C.), and removes essentially all of its dust content. This paper describes the gas-cleaning system and the method used for disposal of the scrub liquor (an acid slurry of oxides and sulphides in an unsaturated solution of soluble salts containing about 2 per cent. SO_2 and 10 per cent. H_2SO_4).

The three sections of the paper are concerned with, respectively, the scrubbing system, scrubber-control features, and electrostatic precipitation, and reference is made to the use of stainless steel (particularly Type 316 17-12-Mo) in the process equipment.

H. G. BURBIDGE: 'Materials of Construction for Slurries Containing Dilute Hydrofluoric Acid', pp. 392-4.

In the electrolytic reduction of aluminium oxide to the metal in a bath of molten cryolite, certain side reactions occur, producing the acid gases hydrogen fluoride and sulphur dioxide. In those operations where Soderberg electrodes are employed, certain volatile hydrocarbons also occur, resulting from the baking of the pitch used in the electrode mix. The reduction pots are enclosed, and the gases are swept out by large volumes of air, and, at the same time, fine alumina dust is picked up from the surface of the bath and is carried out in the air stream. Some particulate fluoride compounds are also entrained. Before release to the atmosphere, these gases are washed to remove the hydrogen fluoride and particulate fluorides. In some cases, the scrubbing equipment operates with alkaline solutions, in some cases, with water, and, in some cases, use is made of a patented acidic recovery system. In this paper the author gives details of plant corrosion tests which have been carried out, and describes the equipment used for the gas scrubbers in the water-washing and acidic process.

Spools containing specimens of the following materials were (1) hung in the gas stream where they would be wet by the washing sprays, and (2) exposed only to the action of humid gas: 'Monel', nickel, 'Inconel', Type 302 and 316 stainless steels, 'Hastelloy B', 'Hastelloy C', copper, lead, aluminium, mild steel, cast iron, 'Ni-Resist II'. The corrosion data presented, together with experience with materials used for the first scrubber, have served as a basis for subsequent plant construction. Of the materials tested, 'Monel', the two stainless steels, 'Hastelloy C' and copper were found to be the most suitable for such service. 'Hastelloy C' was selected for a float in a flow meter, but, of the others, only copper has been used to any great extent (in the form of red brass).

Information on actual service experience with scrubbers is given under the headings of the classes of material employed: wood; polyvinylidene chloride; 19-22-3 chromium-nickel-molybdenum austenitic steel containing 1 per cent. copper; copper and red brass; PVC; concrete; rubber and synthetic elastomers; other synthetic materials.

Heat-Treating Stainless-Steel Strip, Sheet and Plate

M. R. OGLE: 'Heating Stainless-Steel Flat Products.'
Metal Progress, 1961, vol. 79, June, pp. 107-9, 131B, 132.

In this article the author outlines the procedures and equipment employed in annealing strip, sheet and plate in the straight-chromium and austenitic grades of stainless steel.

Annealing facilities and procedures usually employed during hot rolling and cold rolling sheet are described, and, in discussing bright annealing, the author refers to the advantages offered by the vertical type of furnace and describes a typical furnace set-up. Annealing and descaling of stainless-steel sheet and plate form the subjects of the concluding sections of the review.

Determination of Ferrite Content in Austenitic Steels

H. DIETRICH: 'Apparatus for Determining Ferrite Content.'
DEW Technische Berichte, 1961, vol. 1, No. 3, pp. 123-6.

In the introductory section of the paper the author reviews the procedures available for determining the amount of ferrite present in austenitic steels, and comes to the conclusion that they are all unsuitable for practical application. He then goes on to describe a recently developed apparatus which permits ferrite contents to be measured simply and exactly (with an accuracy of $\pm 0{\cdot}5$ per cent.) in the range 0-15 per cent.

The apparatus consists of a flux meter and a cylindrical probe containing a permanent magnet and an induction coil. When the probe is drawn rapidly away from the specimen, the deflexion on the flux meter is proportional to the ferrite content. The specimen must be at least 30 mm. in diameter and 1 mm. thick, and its surface must be clean and smooth.

The apparatus can be applied also to the measurement of permeability at 100 Oe., but the accuracy achieved is relatively low.

Magnetic Technique for Estimation of Ferrite in Stainless-Steel Welds

G. C. CURTIS and J. SHERWIN: 'Magnetic Method for the Estimation of Ferrite in Stainless-Steel Welds.'
Brit. Jnl. Applied Physics, 1961, vol. 12, July, pp. 344–5.

Where duplex structures of austenite and ferrite are formed in welding stainless steels, it may be important to determine the percentage of ferrite present. Several methods are available, and in the variant of the point-count method used by the U.K. Atomic Energy Authority, Windscale, a suitably treated portion of the specimen is examined microscopically, and the proportions are estimated by the interception of ferrite grains on a random line superimposed on the field of view. This method is, however, inherently slow and tedious, and the possibility was therefore examined of basing a more convenient technique on the fact that ferrite is ferromagnetic and austenite paramagnetic. The work carried out in this connexion, and the technique ultimately evolved, form the subject of this note.

The method described is stated to be capable of determining, with an estimated probable error of $\pm 0{\cdot}5$, the percentage of ferrite in a stainless-steel weld, by measurement of the saturation intensity of magnetization of the weld. A calibration curve for 18-8-1 stainless steel is presented and correlated with curves obtained with iron-in-wax specimens.

The technique has the advantage of giving directly the mean value throughout a specimen of convenient size, and thus eliminates the necessity of making, and then averaging, a number of determinations at different points. The authors see no reason why, using modified apparatus, the range of 2–18 per cent. ferrite content actually measured should not eventually be extended.

Flash Welding of Nickel-base High-Temperature Alloys

E. BYLIN: 'A Solution Adopted in Some Difficult Applications of Flash Welding.'
Welding Jnl., 1961, vol. 40, May, pp. 229s–40s.

The work recorded was undertaken with the aim of obtaining flash-welding data which would serve as a preliminary step to the compilation of process recommendations. Two types of material were selected for study: cast iron, and nickel-chromium-base high-temperature alloys containing basically chromium 20, cobalt 0–20, iron 5, aluminium+titanium+silicon 5, nickel 50–75, per cent. The flash welding of cast iron was included within the scope of the study in connexion with its use for joining flanges to centrifugally-cast pipes; the creep-resisting nickel-base alloys were selected for study as representative of those used for jet-engine applications. Both types of material were regarded as difficult to flash weld, and were considered as extreme cases.

Welding was carried out using a machine with automatically controlled motor-operated upsetting, involving an upsetting speed considerably lower than that used in hydraulically operated machines. Welding procedures and equipment are described in detail, and the paper includes data obtained from study of the effects of relevant welding variables, and from tensile tests on, and metallographic examination of, welds produced.

The author concludes that flash welding of cast iron is feasible, provided that accurate control of the upsetting stroke (in combination with a low specific upsetting pressure) is maintained. The low upsetting speed, providing for upsetting without impact, and with exact length of upset travel, precludes any risk of destroying the crystal structure. Using the procedure described, cast iron is readily weldable over a relatively wide range of composition.

With respect to the creep-resisting alloys, the investigation demonstrated that a considerably lower specific upsetting pressure than that required with hydraulic upsetting can be used with the process described, due partly to the possibility of exerting exact control over the upset travel, and partly to the feasibility of controlling the current during upsetting and the possibility of breaking the current at the most suitable moment.

Welding of 'Inconel' for Nuclear-Reactor Applications

R. W. MINGA and W. H. RICHARDSON: 'Use of 'Inconel' Deposited Weld Metal for Nuclear Component Parts.'
Welding Jnl., 1961, vol. 40, July, pp. 726–35.

Test programmes conducted by various interested organizations to determine materials suitable for use in critical applications in nuclear-energy reactors (e.g., under service conditions requiring resistance to stress corrosion) have shown that the nickel-chromium-base heat- and corrosion-resisting alloy 'Inconel' provides an acceptable balance between the characteristics desired and basic economics. Consideration was therefore given to the problem of modifying existing welding processes, and developing new procedures, so as to enable the production of 'Inconel' weldments in the thickness and shapes dictated by design requirements. The applications found by 'Inconel' in the nuclear field now range from 0·05-in.-wall (1·25-mm.-wall) tubing, to reactor sections more than 5 in. (12·5 cm.) thick, its largest single use being for weld overlaying of carbon and low-alloy steels in contact with primary coolants. In this paper the authors review the problems encountered in welding 'Inconel' (principally by means of the gas tungsten-arc and the gas metal-arc processes) to nuclear-quality requirements.

Quality requirements for nuclear-reactor service are considered in relation to relevant codes and specifications, to corrosion-resistance and weld soundness,

and to non-destructive testing. Attention is then given to the problem of ensuring that 'Inconel' welds meet these requirements, and particular emphasis is placed on the significance of the surface condition of the filler wire, the choice of shielding gas, and the physical properties of the deposit.

If welding variables are not carefully controlled, weld defects can result. Fissuring and hot cracking can occur, and the oxides formed on the weld deposits can reduce the wetting action of the molten weld metal and give rise to oxide inclusions and cold laps. Weld porosity can also be a problem. Each of these defects is discussed and illustrated by photomacro- and photomicrographs, and the precautions necessary to prevent their occurrence are referred to.

The last section of the paper is given up to consideration of the welding equipment dictated by quality requirements and component design.

Solution of the basic metallurgical problems is regarded as a prerequisite to progress in overcoming the welding problems associated with 'Inconel'. If the tendency towards fissuring and hot cracking could be reduced significantly by identification of the grain-boundary constituents deemed responsible, rapid progress could be expected both in the development of 'Inconel' submerged-arc fluxes and electrode coatings and in simplifying automatic welding equipment, advances which would greatly reduce the cost of producing weldments to nuclear-quality requirements.

Fabrication and Properties of Welded 'Inconel' Pipe

W. L. FLEISCHMANN and R. F. GURNEA: 'Fabrication of One-Inch Thick, Ten-Inch Diameter Welded 'Inconel' Pipe.'

Welding Jnl., 1961, vol. 40, June, pp. 620–628.

This paper, which was originally presented at the 41st Annual Meeting of the American Welding Society, has been abstracted, from the preprint then available, in *Nickel Bulletin*, 1960, vol. 33, No. 8–9, p. 214.

Welded Nickel-Alloy Tubular-Bladed Turbine Wheel

E. J. CLARK: 'A Welded Tubular-Bucketed Turbine Wheel.'

Welding Jnl., 1961, vol. 40, May, pp. 522–8.

The successful performance of power units operating on the turbine principle is governed to a great extent by design configurations, fabricating practice, and selection of suitable materials. In early turbines, dovetailing was employed as a method of blade attachment, but later designs have proven the effectiveness of a less costly welded construction. In early 1958, realization of the advantages of using tubular-bladed turbine wheels for a two-stage afterburner fuel pump under development for the General Electric Company J-93 mach-3 aircraft engine (savings in weight and cost were found to be very significant) led to the initiation of work to produce a welded design which would ensure high joint efficiency and reliability. This work involved selection of suitable materials and heat-treatments, and the evolution of joint configurations and welding procedures which would satisfy the service requirements of such a highly-stressed rotating component.

A nickel-base alloy of the following composition was selected for use in all the components of the turbine wheel: carbon 0·08 max., manganese 1 max., silicon 0·5 max., sulphur 0·01 max., nickel (+cobalt) 70 min., chromium 14–17, iron 5–9, niobium (+tantalum) 0·7–1·2, titanium 2·25–2·75, aluminium 0·4–1, copper 0·5 max., per cent. In this paper the author discusses the programme initiated to develop suitable welding techniques for fabricating the wheel, and gives details of the procedures ultimately developed and the tests carried out to evaluate performance characteristics.

The tests and performance data indicate that such welded turbine wheels successfully meet all the requirements entailed in driving the afterburner fuel pump for the mach-3 aircraft engine. The wheel discussed by the author is limited to operating temperatures in the range 1000°–1200°F. (540°–650°C.), but it is planned to explore the feasibility of extending the design concept to materials suitable for higher-temperature service.

Welding and Heat-Treatment Procedures for 'P.H. 15-7 Mo' Sheet

H. SMALLEN: 'Welding 'P.H. 15-7 Mo' Precipitation-Hardening Stainless Steel.'

Welding Jnl., 1961, vol. 40, July, pp. 324s–9s.

The chromium-nickel-molybdenum precipitation-hardenable stainless steel 'P.H. 15-7 Mo' possesses elevated-temperature properties which render it suitable for use as a material of construction in high-speed aircraft and guided missiles. Since in such applications the steel will often have to be fusion welded and/or resistance welded, an investigation was initiated to determine satisfactory welding and heat-treatment procedures for sheet material 0·063 in. (1·575 mm.) thick. The results of the study are reported in the present paper.

The heat-treatments and welding sequences selected for evaluation with both welding techniques represented methods of (1) obtaining optimum strength, (2) obtaining increased ductility with some sacrifice in strength, and (3) obtaining a satisfactory compromise in properties where the shape and size of the assembly would prevent high-temperature heat-treatment following welding. 'P.H. 15-7 Mo' wire was used as filler metal. Full details are given of the welding procedures and heat-treatments employed, and hardness curves and data on mechanical properties are presented for each weldment and heat-treatment sequence investigated. Photomicrographs

and photomacrographs illustrating the structure of the welds studied are included in the paper.

The steel is, it is concluded, readily weldable with standard fusion- and resistance-welding equipment. Ultimate-tensile-strength values approximating to 100 per cent. of the parent-metal strengths were found to be obtainable in fusion weldments subjected to austenite conditioning and transformation treatments after welding, whilst highest lap shear values for resistance weldments resulted from welding after transformation and before the final hardening treatment.

Welding Chromium-Molybdenum Steel to 17-12-Mo Stainless Steel for High-Temperature Service

ALCO PRODUCTS, INC.: 'Welded Transition Joint between 2¼% Cr-1% Mo Steel and Type 316 Stainless Steel.'

U.S. Atomic Energy Commission, Report APAE-72, Aug. 15, 1960; 59 pp.

The test programme reported was undertaken in connexion with work on a proposed steam-generator designed by ALCO Products, Inc., to produce superheated steam using liquid sodium as a heating medium. In the interests of operating efficiency and compactness, and to eliminate the need for an external piping system, the boiler, steam drum and superheater were to be integrated into a single unit. A.I.S.I. Type 316 17-12-2Mo steel was selected for use in all sections of the superheater, and 2¼ per cent. chromium-1 per cent. molybdenum steel for the boiler and steam drum. To fabricate the integrated steel generator, it was necessary to produce a transition joint between the chromium-molybdenum steel and the austenitic stainless steel which would exhibit metallurgical and mechanical properties ensuring satisfactory performance of the unit when subjected to a nominal design temperature of 700°F. (370°C.). The research programme described in the present report was initiated with the aim of developing a procedure for welding a transition joint between heavy (1-in. and 4½-in. (2·5- and 11·25-cm.)) forged sections of chromium-molybdenum steel and Type 316 stainless steel, and to evaluate the weld by mechanical testing and metallographic examination.

After assessing the technical aspects of the project, and their relation to the fabrication of the generator, it was considered desirable to overlay the welding edge of the low-alloy steel with a suitable austenitic weld metal, which would then be welded to the Type 316 steel of the superheater. Both austenitic-stainless-steel and high-nickel-alloy weld metals were evaluated to determine a suitable material for the overlay, but only austenitic-stainless-steel weld metals were tested for use in welding the joint between the components.

Type 309 23-13 chromium-nickel stainless-steel weld metal, deposited automatically by the submerged-arc process, was found to provide a completely satisfactory overlay for the low-alloy-steel basis metal, and to be equally suitable for use in the final transition weld between the steam drum and the superheater section of the generator. Supplementary mechanical tests, metallographic examination and hardness surveys verified the adequacy of the transition joint produced by the procedures developed.

Full details of these procedures are contained in an *appendix* to the report, the three sections of which cover: (1) welding of the Type 309 stainless-steel overlay onto the end of the low-alloy-steel transition section: (2) welding and heat-treatment of the 'Inconel' cladding deposited on the inner surface of the overlay/basis-metal interface; and (3) groove welding of the overlayed low-alloy-steel transition section to the Type 316 stainless-steel basis metal.

Development of Ductile Nickel-base Brazing Alloys

R. A. LONG: 'Development of New Nickel-base Brazing Alloys Having Ductility.'

Welding Jnl., 1961, vol. 40, June, pp. 259s-64s.

The investigation reported was initiated with the aim of developing nickel-base brazing alloys with higher ductility than those commercially available at the time (1959). The author comments that such a development programme confronts the metallurgist with a disconcertingly wide range of variables and limitations, since in no other field has an alloy, both in the molten and solid state, to meet so many fundamental requirements. The present paper was written therefore not only to describe the newly developed alloy series, but also to outline a development method 'which obtained results with a minimum of effort'.

Consideration was first given to the fundamental requirements which an alloy must meet to offer promise of development as a brazing material. In this connexion, the author discusses the properties desired in the chill-cast condition, brazing characteristics, and the aspects which must be taken into account in assessing the suitability of the brazing alloy for a particular application.

A survey of various relevant alloy systems led the author to select the nickel-molybdenum as the most promising, and then to search the ternary diagrams available in the literature for a third element which would depress the liquidus of the system. On the basis of this search, a test programme was undertaken to establish the characteristics of the nickel-molybdenum-silicon system at nickel contents in excess of 60 per cent. Screening tests to evaluate casting and brazing characteristics showed that, as the nickel content was raised and the molybdenum-silicon content lowered, the alloys became less hard and more ductile, but only at the expense of an increase in the liquidus/solidus temperature.

In the following phase of the study, a nickel-base alloy containing molybdenum 17 and silicon 9·6 per cent., was selected as a basis for the evaluation of the effects of individual additions of manganese (an element which is known to depress the

Nickel-base Ductile Brazing Alloys
(*See abstract on p. 268*)

Composition							Liquidus Temp.		Braze Flow Temp.		Hardness R_C
Ni %	Mo %	Si %	Mn %	Cr %	Sn %	Fe %	°F.	°C.	°F.	°C.	
†61·0	10·7	4·76	18·2	4·5	—	0·8	2080	1135	2150	1175	30-33
†66·0	16·2	7·65	5·9	—	3·5	0·7	2050	1120	2150	1175	40
†54·7	14·0	5·8	25·0	+	—	—	—	—	1925	1050	44
*69·7	13·7	6·9	8·3	—	—	1·3	—	—	2100	1150	44
*82·0	8·7	4·2	5·0	—	—	0·5	—	—	2200	1205	33
†82·3	8·7	1·7	5·0	—	—	2·3	2350	1285	2400	1315	R_b 72

† Produced in powder form by atomization. * Produced in shot-cast form.

melting point of nickel), chromium (selected for study on account of its use in oxidation-resistant nickel-base alloys), cobalt and iron. Manganese was found to have the most effect in lowering the liquidus/solidus range and in increasing wetting characteristics. Chromium additions were not detrimental, except in increasing the liquidus temperature. Cobalt and iron were not beneficial.

Although many specific types of brazing alloy could be evolved from the alloy systems investigated, in the experiments described in the concluding section of the paper development of ductile brazing materials was the main aim. The alloy series selected for study were of high nickel content and of low total molybdenum and silicon content. The effects of chromium, tin, beryllium and lithium were evaluated, and an attempt was made to produce wide-gap-brazing alloys by additions of iron or cobalt. Data were obtained on oxidation-resistance as well as brazing characteristics.

The performance of the six alloys selected for further consideration are discussed. Their composition, liquidus temperature, braze-flow temperature, and hardness are reproduced in the table above.

Wide-Gap Brazing of Components for High-Temperature Service

P. R. MOBLEY and G. S. HOPPIN: ' 'Wide-Gap' Brazing for High-Temperature Service.'
Welding Jnl., 1961, vol. 40, June, pp. 610–17.

The application of furnace brazing to the fabrication of large sheet-metal structures has in the past been inhibited by the joint clearances required to ensure the necessary capillary attraction (0·002–0·006 in. (0·05–0·15 mm.)). In recent years, however, experimental work has led to the development, and successful use, of techniques permitting the production of brazed joints at joint clearances as wide as 0·06 in. (1·5 mm.). Such 'wide-gap' brazing forms the subject of the present paper.

The development of the new brazing materials and techniques for wide-gap brazing described by the authors originated in the need for an improved fabrication process for jet-engine turbine nozzle assemblies. These components are often fabricated from high-temperature alloys relatively difficult to weld, and the fact that the parts are large enough to result in fit-ups ranging from line contact to a 0·06-in. (1·5-mm.) gap, precludes the use of conventional brazing techniques. It was known at the outset of the development work that any material for brazing large-gap joints must possess exceptionally sluggish flow characteristics. It had previously been discovered that the addition of 20 wt. per cent. of elemental nickel powder to 'J8100' brazing powder (nickel 70, chromium 20, silicon 10, per cent.) produced a brazing material ('J8102') which had flow properties inferior to those of 'J8100'. On the assumption that the poor flow properties imparted by the nickel additions might be utilized to develop an unconventional brazing material for brazing wide-joint gaps, initial work was concentrated on the effects of adding various percentages of elemental nickel powder to powder brazing alloys, but subsequent development work showed that blending of diverse alloy powders was the key to successful production of wide-gap brazing materials. The mechanism by which such materials bridge large gaps was postulated as involving the melting, at brazing temperature, of one alloy powder and not the other. This effect results in the formation of a viscous slurry, with poor flow characteristics, wherever the powders have been preplaced. The slurry then metallurgically bonds itself to the two abutting members of the joint.

Experimental work initiated in 1956 resulted in the evolution of the first truly wide-gap brazing material for elevated-temperature use (designated 'J8101'). Although 'J8101' produced satisfactory joints, its high brazing temperature rendered it unsuitable for many applications, and consequently work was

Nickel-base Wide-Gap Brazing Alloys
(*See abstract on p. 269*)

Brazing Material	Composition wt. per cent.						Solidus temp.		Liquidus temp.		Brazing temperature		Remarks
	Ni	Cr	Si	Cu	Mn	B	°F.	°C.	°F.	°C.	°F.	°C.	
'J8100'	Bal.	20·0	10·0	—	—	—	2030	1110	2075	1135	2125-2175	1163-1190	Capillary brazing alloy
'J8590'	28·0	—	2·0	Bal.	10·0	—	1850	1010	2000	1095	2050-2100	1120-1150	Capillary brazing alloy
'NSB'	Bal.	—	2·0	—	—	0·8	1980	1080	>2300	>1260	>2300	>1260	Used as filler alloy for wide-gap brazing
'J8101'	60% 'J8100' + 40% nickel powder										2240	1225	Wide-gap brazing material
'J8105'	70% 'J8100' + 30% 'NSB' powder										2125-2175	1163-1190	Wide-gap brazing material
'J8591'	80% 'J8590' + 20% iron powder										2050-2100	1120-1150	Wide-gap brazing material

NOTE : All powders used are —100 mesh materials.

instituted to evolve a variant having a lower brazing temperature. This work revealed that the nickel-powder constituent could be replaced with 'NSB' alloy, the silicon and boron contents of which were sufficiently low to allow only slight melting of the alloy at brazing temperatures of 2100°-2200°F. (1150°-1205°C.). It was found that mixtures of 'J8100' and 'NSB' alloy could be used to produce wide-gap joints in the brazing range 2125°-2150°F. (1163°-1175°C.) at 20-40 wt. per cent. of 'NSB': brazing alloy 'J8105' was developed from this system.

Experiments carried out to apply the wide-gap brazing principle to a number of other alloy systems have shown that a similar effect can be obtained with additions of copper powder to silver-alloy brazing powders, and of iron powder to a copper-base brazing alloy powder. The material resulting from the latter combination has been designated 'J8591'. The compositions and brazing temperatures of the brazing alloys referred to are given in the table above.

Of the variables influencing the success of the wide-gap furnace-brazing process, the authors discuss the following in a guide to the precautions to be taken into account in brazing high-temperature components: (1) joint design and joint clearances; (2) cleanliness of the joint faying surfaces; (3) joint or part fixturing; (4) application of the brazing material; (5) brazing-temperature measurement; (6) brazing thermal cycles.

Data illustrating the mechanical properties of wide-gap-brazed joints are presented, and reference is made to the successful application of the process to a number of experimental and production jet-engine parts. Among the brazed components illustrated in the paper is an 'Inconel X' jet-engine exit frame assembly over 6 feet in diameter and containing more than 700 brazed joints. Some of the jet-engine parts brazed by the technique are stated to be in service at temperatures up to 1800°F. (980°C.).

Wetting Tests on 'Inconel' and 'Inconel X' with Silver Brazing Alloys Containing Platinum Metals

J. B. ADAMEC and R. N. RHODA: 'Influence of Some Platinum Metals on the Wettability of Silver.' *Welding Jnl.*, 1961, vol. 40, July, pp. 330s-6s.

Palladium is frequently used as a constituent of high-temperature brazing alloys. The study reported by the authors, which formed part of an investigation designed to develop brazing alloys suitable for use with nickel-base heat-resisting alloys, was undertaken to determine the influence of alloying additions of palladium and other platinum metals on the wetting characteristics of silver.

Contact angles for binary silver-base alloys containing up to 20 wt. per cent. palladium, up to 20 wt. per cent. platinum, or 5 wt. per cent. ruthenium, and for ternary silver-base alloys containing up to 8·7 wt. per cent. palladium and up to 15·2 wt. per cent. platinum, were determined in wetting tests on 'Inconel' and 'Inconel X' in various furnace atmospheres.

Wetting of 'Inconel' in both hydrogen and argon atmospheres was generally enhanced by the presence of palladium and platinum, an effect which is attributed to the formation of a palladium- or platinum-rich phase which is immiscible in the silver alloy. This noble phase wet and flowed readily on the 'Inconel' surface, forming a film which, in turn, was wet by the silver-rich phase. The same mechanism of wetting was encountered in tests on 'Inconel X' (an age-hardenable nickel-chromium alloy containing aluminium and titanium), but wetting was enhanced to a lesser degree, due to the presence, on the basis metal, of oxide films which interfered with the formation and spread of the noble phase.

Under slightly oxidizing conditions, the platinum content of the silver alloys was a more important factor than the palladium content in improving wetting characteristics. This finding is explained

in terms of the greater oxidation-resistance of the platinum alloys, and the ability of the alloys to undermine and wet the oxide films.

ANALYSIS

Determination of Zinc in Nickel Electrolytes

See abstract on p. 248.

Spectroscopic Standard Samples for Nickel-containing High-Temperature Alloys

See abstract on p. 260.

PATENTS

Separation of Nickel from Cobalt

The invention is directed towards the separation of small amounts of nickel from a solution containing cobalt, and permits recovery of cobalt substantially free from nickel.

Nickel is precipitated from an ammoniated solution, containing dissolved salts of nickel and cobalt (in a cobalt/nickel ratio of less than about 100/1), by reacting the solution with a sulphur-free reducing gas at elevated temperature and pressure. The ammonia content of the solution is adjusted to at least 2 mols of ammonia per mol of nickel, and the reducing reaction is conducted in the presence of added finely divided cobalt-metal particles. The reducing reaction is continued, to precipitate nickel onto the cobalt particles, until the cobalt/nickel ratio in the solution is greater than 100/1, and the nickel-cobalt metal particles are then separated from the solution.

SHERRITT GORDON MINES, LIMITED (inventors, R. L. BENOIT, V. N. MACKIW and W. C. LIN).

Brit. Pat. 876,856.
Similar to *U.S.* „ 2,822,262.
„ „ *Canad.* „ 553,403.
„ „ *Belgian* „ 563,395.
„ „ *German* „ 1,110,878.

Fluid-Bed Roasting of Sulphides for Removal of Sulphur

The invention is based on the finding that the difficulties arising from fusion when sulphidic materials, such as low-melting sulphides (e.g., nickel sulphides), are fluid-bed roasted at temperatures above their softening point, but below the melting point of the resulting calcine, can be largely, or wholly, avoided by supplying the sulphide material to the bed in the form of granules or agglomerates, and supplying the oxygen-containing gas at a rate sufficiently high to elutriate fines from the bed, while maintaining the coarser granules or agglomerates in a fluidized condition.

Accordingly, the patent covers a process for fluid-bed roasting a sulphide material (containing one or more of the metals nickel, cobalt and copper, with or without iron) in an oxygen-containing gas at a temperature above the softening point of the sulphide material but below the melting point of the resulting calcine. In a preferred process, the agglomerates contain fuel oil or are bound with nickel sulphate, sulphuric acid or calcium lignosulphonate. When the invention is applied to nickel-sulphide-containing materials, the roasting is followed by activation with oxygen-containing gas at 675°–790°C.

INTERNATIONAL NICKEL COMPANY OF CANADA, LIMITED.

Brit. Pat. 875,554.

Preparation of Ferrous Metals for Direct Enamelling

In a process for direct enamelling of ferrous metals, the surface of the basis metal is treated prior to enamelling by being cleaned, heat-treated in an oxidizing atmosphere (preferably in the range 1100°–1250°F. (595°–675°C.)) for a period sufficient to oxidize 1–4 grams of basis metal per square foot of surface, etched or abraded to remove all the oxide, rinsed in running water (preferably acidified to a pH of 5·0–6·5), and subsequently coated with 0·05–0·25 grams of nickel per square foot of surface.

The heat-treatment, eradicating any variation in the surface condition of different lots of steel as received from the mill, ensures consistency of etching, hence eliminates any variation in the rate of nickel deposition arising from differences in etching, and thereby ensures blemish-free enamelling.

FERRO CORPORATION (inventors, V. R. LUSTER and E. E. BRYANT).

Brit. Pat. 872,688.

Electrolyte for Nickel-Cadmium Batteries

The patent covers an electrolyte for nickel–cadmium batteries, and for counter e.m.f. cells of the type using negative electrodes of cadmium or porous nickel, which is stated to increase the capacity and life of a sealed battery, permit the battery to be operated on continuous overcharge at high rates without undue build-up of gas pressure, and permit it to be sealed with a non-critical amount of electrolyte (thereby eliminating the so-called 'inverted charge' hitherto necessary in the manufacture of such batteries).

The alkaline electrolyte contains a salt of a halogen selected from chlorine, bromine or fluorine, in an amount ranging from 1–10 molar per cent. by weight

of the electrolyte. A preferred electrolyte contains: water 87·7, potassium hydroxide 7, a potassium halide 5·3, molar per cent.

ELECTRIC STORAGE BATTERY COMPANY.
Brit. Pat. 870,697.
Similar to *German* „ 1,108,286.

Sealed Nickel-Cadmium Battery

An improved sealed nickel-cadmium secondary cell incorporates an anti-polar mass with minimum sacrifice of space and without disturbance to the electrochemical structure of the cell. The anti-polar mass is incorporated in the form of two auxiliary electrodes of a cathodic reducible oxide (such as cadmium oxide or, preferably, cadmium hydroxide) separated by a spacer screen of sufficient thickness, and of appropriate structure, to permit gas circulation, this arrangement being disposed between two semi-cylindrical pieces of nickel-hydroxide mix which make up the positive electrode. The oxygen gas which evolves at the negative electrode upon polarity reversal is thus provided with easy access to the anti-polar mass, and, in the event of the cell reversing polarity, the cadmium-hydroxide auxiliary electrodes will be partially reduced to cadmium metal, and no hydrogen gas will be generated at the positive electrode. The oxygen gas evolving from the negative electrode will collect within the space provided by the spacer screen, and react directly with the exposed surfaces of the reduced auxiliary electrodes and once again oxidize the cadmium metal.

J. L. S. DALEY, assignor to UNION CARBIDE CORPORATION.
U.S. Pat. 2,980,747.

Improved Fuel Cells

The object of the invention is to improve the current-carrying capacity and the voltage efficiency of fuel cells by obviating to some extent the loss due to activation energy at the electrodes. It has been found that certain materials which are non-stoichiometric reduce the activation energy in some reactions, and increase the activation energy with the reverse reaction. In the fuel cell claimed, the electrodes therefore have surface portions in contact with the electrolyte composed of non-stoichiometric material. In the case of the fuel electrode, the material is one having an excess of its electro-negative constituent, while, in the case of the other (e.g., the oxygen or halogen) electrode the material is one having an excess of its electropositive constituent.

The fuel electrode preferably consists of a sintered porous mass of powdered nickel, throughout which is applied a firmly adherent layer of black nickel oxide. Other preferred compounds with an excess of electro-negative constituent are ferrous oxide, cuprous oxide, cobalt oxide, uranium oxide, ferric sulphide and chromium sulphide. The surface portion of the other electrode preferably consists of zinc oxide or cadmium oxide with an excess of the metal constituent due to interstitial cations, or of a metallic compound such as thoria or ceria having anion vacancies and excess metal.

NATIONAL RESEARCH DEVELOPMENT CORPORATION (inventor, C. G. CONWAY).
Brit. Pat. 877,410.

Electrode for Hydrogen-Oxygen Fuel Cells

According to the present invention, an electrode for use in a hydrogen-oxygen cell consists of a flat metal supporting plate, with, on at least one side, a coating of porous nickel which has provision for access of gas at its rear side (e.g., by means of small holes through the plate), and which comprises an underlying layer of relatively coarse pore size formed with a rounded or chamfered edge, and an overlying layer of finer pore size which is extended at its periphery over the chamfered edge of the coarse-pore layer into contact with the supporting plate (to which it is secured over an annular area of width appreciably greater than the thickness of the fine pore layer itself). Preferably the layer of coarse-pore nickel is first sintered into position on the supporting plate, the edge of the layer is rounded or chamfered, and the layer of fine-pore nickel is then applied over the coarse-pore layer.

The improvement lies in the elimination of the tendency of the sintered layers, particularly the outer fine-pore layer, to shrink away from the edges of the recess incorporated for their retention in previous electrodes.

NATIONAL RESEARCH DEVELOPMENT CORPORATION (inventor, F. T. BACON). *Brit. Pat.* 871,950.

Production of Nickel Carbonyl

A method of producing nickel carbonyl, by reacting carbon monoxide with a liquid charge comprising an aqueous mixture of ammonia and a water-soluble nickel compound at a temperature of at least 75°C. under pressures greater than atmospheric, is characterized by the following features: (1) the liquid charge is introduced continuously into the reaction zone, where it is brought into contact with carbon monoxide at a space velocity of at least 1000 (preferably 2000–8000) vol./vol./hour; (2) the pressure employed is one of 66–660 (preferably 100–330) atmospheres; (3) the temperature is of the order of 150°–240°C.; (4) the ammonia/nickel molar ratio is between 6 and 10; (5) the ammoniacal aqueous charge and the aqueous nickel-salt mixture are introduced separately into the reaction zone; (6) the space velocity of the liquid stream is 0·5–10 vol./vol./hour; (7) the nickel compound is a nickel hexammine complex.

UNION CARBIDE CORPORATION (inventors, E. V. KING and T. R. SMITH). *French Pat.* 1,254,252.
See also *Brit. Pat.* 876.952

Gas Plating of Synthetic Fibres Using Nickel Carbonyl

The invention is stated to be particularly applicable to gas plating fibres and fabrics, made of natural or synthetic resins, which tend to soften or change physically when subjected to the relatively high temperatures ordinarily employed in gas-plating operations.

According to the claims of the patent, heat-sensitive organic fibres which tend to soften under prolonged heating at 350°–475°F. (175°–245°C.) are gas plated in an apparatus comprising a series of gas-plating and interposed cooling chambers, and incorporating a means of drawing the fibres through the chamber at a predetermined rate. Each gas-plating chamber is connected directly with a source of heat-decomposable metal-bearing compound suitable as a medium for gas plating, and with a cooling chamber in which the fibre is quickly cooled after gas plating.

The specification includes examples illustrating the gas plating of nylon and 'Saran' with nickel (using nickel carbonyl) and of 'Orlon' with iron (using iron carbonyl).

H. A. TOULMIN, assignor to UNION CARBIDE CORPORATION. *U.S. Pat.* 2,986,115.

Recovery of Nickel Carbonyl Present in Exhaust Gases from Gas-Plating Operations

The recovery of metal-bearing compounds present in the exhaust gases associated with metallizing operations involving the use of thermally decomposable [metal-bearing compounds is generally effected by means of relatively expensive equipment based on refrigeration techniques. The purpose of the present invention is to provide a method of recovery 'which is efficient and economical, and thus contributes to the overall success of the metallizing operation; which does not require a costly installation of complex equipment; and which produces a recovered product free of contamination'.

According to the invention, nickel carbonyl is recovered, in the liquid state, from the exhaust gases of gas-plating operations by: flowing the exhaust gases into water maintained at a temperature sufficient to condense only the nickel carbonyl; settling the condensed nickel carbonyl by gravity to separate it from the water; and subsequently drying it.

The application of the process to the recovery of other thermally decomposable metal-bearing gaseous carbonyls is also claimed.

E. R. BREINING and W. M. BOLTON, assignors to UNION CARBIDE CORPORATION.

U.S. Pat. 2,985,509.

Production of Nickel Coatings with Improved Corrosion-Resistance

The inventor's investigations have shown that coatings electrodeposited from nickel-plating solutions containing certain addition agents exhibit a resistance to chemical corrosion 100 per cent. higher than that of conventional dull-nickel coatings. These agents include coumarin and acetylenic compounds (especially the acetylenic alcohols and the esters and esthers of these alcohols). The patent therefore relates to an electroplating solution for deposition of a highly corrosion-resistant nickel coating, the solution containing (in amounts sufficient to achieve increased corrosion-resistance in the deposit) coumarin and one or more of the following: acetylenic alcohols, acetylenic esters and acetylenic esthers; or acetylenic derivatives of coumarin compounds.

H. ERICSON, assignor to KEMISKA AKTIEBOLAGET. *Canad. Pat.* 624,131.

Electrodeposition of Zinc-Nickel Alloys

The invention is intended to provide a solution to the problem of obtaining an adherent chromium or nickel overcoating on a zinc-rich nickel-zinc-alloy coating deposited on a ferrous substrate to improve corrosion-resistance.

The component (e.g., a steel automobile bumper) is plated in a solution (pH 1–3; temperature 70°–165°F. (20°–75°C.)) containing salts of nickel and zinc in amounts to give a nickel-metal content of 8–10 oz./gal. (49·9–62·4 g./L.) and a zinc-metal content of 6–8 oz./gal. (37·4–49·9 g./L.), at least 50 per cent. of the total nickel and zinc metal concentration being in the form of chlorides. Current is passed through the component and electrolyte in a direction such as to make the component continuously cathodic and to deposit a coating of zinc-rich alloy. The current flow is then periodically reversed to make the component alternately anodic and cathodic, with the result that a nickel-rich zinc alloy is deposited over the zinc-rich alloy. The component may then be plated with nickel or chromium.

M. B. HAMMOND and G. B. BOWMAN, assignors to ROCKWELL-STANDARD CORPORATION.

U.S. Pat. 2,989,446.

High-Manganese Nickel-Aluminium Bronze

Brit. Pat. 727,021 covers an alloy containing manganese 10–15, aluminium 6·5–9, iron 2–4, nickel 1·5–6, per cent., and Brit. Pat. 809,973 narrows the range of the aluminium content to 3·5–<6·5 per cent. Such alloys have good casting and welding characteristics. The present invention is based on the finding that good mechanical properties can be obtained at manganese contents higher than 15 per cent., provided that use is made of high-purity manganese. Properties of alloys falling within the range covered are stated to be outstanding (data typifying properties are included in the specification).

The copper-base alloys covered are of basically duplex character, consisting mainly of an alpha phase and a beta phase. They contain: manganese 15–35, aluminium 3·5–9·5, iron 2–4, nickel 6 max.

and/or tin 2 max., per cent. In the absence of tin, the minimum nickel content is 1 per cent., and, in the absence of nickel, the minimum tin content is 0·25 per cent. When both elements are present, the nickel content plus four times the tin content is not less than 1 per cent. The aluminium equivalent of the aluminium and manganese present lies within the range 9–12 per cent. Where the alloy is used for the production of castings such as marine propellers, the aluminium equivalent should be about 10 per cent.

J. STONE AND COMPANY (PROPELLERS), LTD., (inventors, A. W. O. WEBB, N. BAILEY and R. T. SOUTHIN).
S. African Pat. 73/61.

Glass-to-Metal Sealing Alloys*

An alloy with good working characteristics and with a coefficient of thermal expansion which renders it suitable for use in soft-glass/metal seals contains (preferred values are given in parentheses): nickel 30–45 (30–32), cobalt 15–25 (20), copper 5–15 (5–6), manganese or titanium up to 0·7 (0·5), chromium up to 0·5 (0·3), per cent., remainder iron.

H. RINGPFEIL and J. MÖCKEL.
E. German Pat. 20,726.

Production of Glass-to-Nickel Seals

Previous attempts to produce reliably air-tight seals between nickel and glass (e.g., in the fabrication of semiconductor devices such as transistors) have, according to the inventor, failed due primarily to the fact that the nickel-oxide film formed on the nickel substrate is insufficiently adherent to provide a bonding bridge between the nickel and the glass. The present invention is therefore aimed at providing (1) effective non-gassy hermetic glass-to-nickel seals, and (2) a method of oxidizing nickel to produce a strongly adherent film of oxide which is both undisturbed by the temperatures normally employed in the glassing process, and readily wetted by ceramic and vitreous materials.

The procedure claimed entails heating the nickel in an oxidizing atmosphere (at a temperature above approximately 1000°C. but below the melting point of nickel) sufficiently long to produce an oxide layer of predetermined thickness, and subsequently quenching the nickel in a non-oxidizing environment and forming the glass-to-nickel seal.

The application of the invention to the production of stems for hermetically sealed semiconductor devices is claimed.

A. J. CERTA, assignor to PHILCO CORPORATION.
U.S. Pat. 2,988,853.

* See, in connexion with this patent, the paper by Ringpfeil and Henkel reporting work on the influence of copper on the expansion behaviour of iron-nickel-cobalt alloys: abstract in *Nickel Bulletin*, 1961, vol. 34, No. 9, pp. 221-2.

Filler Rod for Welding Grey Cast Iron

In oxy-acetylene welding of grey cast iron, use of filler rods of the following composition is stated to permit the production of welds containing, at most, only small amounts of eutectic carbide, and thereby exhibiting improved mechanical properties: carbon 3·5–4·5, manganese 0–0·15, silicon 2–3, nickel 3–7, cobalt 0–2, aluminium 0·05–0·2, magnesium 0·01–0·2, per cent., remainder iron.

In a preferred process, a borax flux comprising a graphitizing innoculant other than carbon is employed, and the weld deposit is subsequently softened by flame tempering at temperatures up to 650°C. to decompose any martensite present.

The application of the process to the welding of S.G. iron is specifically claimed.

INTERNATIONAL NICKEL COMPANY (MOND), LIMITED (inventors, R. H. T. DIXON and D. R. THORNEYCROFT).
Brit. Pat. 874,405.

Air-Hardenable Graphitic Steels

The aim of the invention is to provide graphitic steels (1) capable of being air-hardened to a minimum hardness of Rc 58 (and preferably at least Rc 60) throughout a section as great as 6 in. (15 cm.) in diameter; (2) capable of being produced and processed easily by standard graphitic-steel practice; (3) possessing good machinability; (4) with dimensional stability comparable to that of competitive non-graphitic steels; (5) capable of being hardened at comparatively low temperatures. After hot working and air cooling from austenitizing temperature, the steel (containing carbon 1–2, chromium 0–0·2, manganese 1·7–2·5, molybdenum 1·3–1·75, nickel 1–2·5, silicon 1–1·5, per cent., remainder iron) exhibits a structure having spheroidized carbides and at least 0·2 per cent. of graphitic carbon distributed throughout its section.

TIMKEN ROLLER BEARING COMPANY.
Brit. Pat. 871,167.
Similar to *U.S.* „ 2,883,281.
„ „ *Canad.* „ 584,322.

Nickel-containing Wear-Resistant Cast Steel

The cast steel covered by the patent is stated to exhibit exceedingly high toughness and resistance to wear, without tendency to deform in service. It is characterized by a fine-grain predominantly martensitic microstructure, a Brinell hardness value of 444 or more, and a Charpy impact value of 1·66 kgm. or more at room temperature and 1·38 kgm. or more at −40°C. The steel is machinable at a Brinell hardness up to 515, and is unusually resistant to corrosion.

The following composition is claimed: carbon 0·2–0·5, manganese 0·15–2·5, silicon 0·1–2, phosphorus 0–0·05, sulphur 0–0·07, molybdenum, chromium and tungsten (singly or in combination) 0–5, nickel 0–4, boron 0·0005–0·005, rare-earth metals 0·0015–0·5, wt. per cent., remainder iron. The steel is preferably normalized at 870°–1040°C., air cooled,

hardened at 815°–925°C., quenched, tempered at 95°–315°C., and quenched.

H. G. BOULY (communicated by AMERICAN STEEL FOUNDRIES).

Brit. Pat. 874,488.
Similar to *S. African* „ 3193/58.
„ „ *Canad.* „ 613,598.

Low-Alloy Steels for Generator Rotor Shafts

The steels of the invention exhibit, it is stated, a remarkable combination of high yield and tensile strengths, good magnetic properties and low impact-transition temperatures, and are therefore ideally suitable as materials for generator rotor shafts. They contain carbon 0·1–0·5, manganese 0·2–1, silicon 0–1, nickel 3·75–8, molybdenum 0·07–1, vanadium and/or niobium 0·02–0·5, chromium 0–2, per cent., remainder iron.

Preferred steels containing carbon 0·15–0·3, manganese 0·2–0·6, silicon 0–0·4, nickel 5–7, molybdenum 0·2–0·5, vanadium and/or niobium 0·02–0·3, chromium 0–0·5, per cent., are characterized, in the normalized-tempered condition, by a microstructure displaying a randomly distributed ferrite-carbon aggregate formed only from tempered bainite and tempered martensite.

INTERNATIONAL NICKEL COMPANY (MOND), LIMITED.
Brit. Pat. 875,913.

Neutron-absorbing Body

The present invention modifies that, covered by Brit. Pat. 838,442, relating to a powder-metallurgically produced neutron-absorbing solid comprising a discrete phase (which has a high neutron-absorbing capacity) dispersed in a matrix, both being stable at temperatures up to 900°C. The body is enclosed in a covering of stainless steel or other corrosion-resisting alloy to form a neutron-absorbing device.

According to the present invention, the shaped body in such a device is cylindrical. A powdered mixture of the matrix material and neutron-absorbing phase is packed between inner and outer tubes, and the assembly is drawn through a die over a mandrel in successive reduction stages. Between successive reductions, the unit is annealed at high temperatures to bond together the constituents of the body by sintering.

INTERNATIONAL NICKEL COMPANY (MOND), LIMITED (inventors, D. K. WORN and R. E. BUTTRESS).
Brit. Pat. 872,060.

Nickel-base Alloy for Nuclear Reactor Service

The invention is intended to provide a material, which, suitable for service in neutronic reactors, is easily formed, exhibits mechanical properties similar to those of nickel-base alloys previously available, and, in particular, is resistant both to oxidation and fused-salt corrosion and does not embrittle under high-temperature reactor service.

The alloy claimed contains molybdenum 15–22, chromium 0–8, carbon 0·02–0·5, wt. per cent., remainder nickel. It may also contain up to 6 per cent. iron, or, as strengthening agents, one or more of the elements tungsten, tantalum, vanadium and niobium up to a total content of 0–4 wt. per cent.

U.S. ATOMIC ENERGY COMMISSION.
Brit. Pat. 871,120.
Similar to *U.S.* „ 2,921,850.
„ „ *Canad.* „ 616,911.
„ „ *French* „ 1,229,765.

Nickel-containing Plutonium-base Alloys for Use as Nuclear-Reactor Fuels

Brit. Pat. 860,161 covers three binary plutonium eutectic alloys having characteristics which render them suitable for use as liquid-metal fuels in nuclear reactors (see abstract in *Nickel Bulletin*, 1961, vol. 34, No. 4, pp. 110–11). These plutonium-cobalt, plutonium-nickel and plutonium-iron alloys have a relatively high plutonium content, and the fuel is not diluted volumetrically to a sufficient extent to attain a high specific power.

The low-melting-point diluted plutonium alloys claimed in the present patent as nuclear-reactor fuels contain (1) cobalt 10–15, plutonium 88 max., at. per cent., remainder cerium, or (2) nickel or nickel + cobalt 10–25, plutonium 86 max., at. per cent., remainder cerium.

U.S. ATOMIC ENERGY COMMISSION.
Brit. Pat. 874,854.
Similar to *U.S.* „ 2,901,345.

Age-Hardenable Copper-base Alloys

Age-hardenable copper-base alloys containing additions of nickel and silicon or manganese and phosphorus exhibit high strength properties when subjected to an appropriate combination of cold working and heat-treatment. Frequently, however, silicide precipitation at the grain boundary has an adverse effect on workability. The present invention is based on the finding that grain-boundary precipitation of silicides can be prevented by alloying additions of 0·05–0·5 per cent. chromium, in the presence of which the silicides precipitate *within* the grains rather than at the grain boundaries.

The copper-base age-hardenable alloys containing silicides of nickel and iron covered by the patent are of the following composition: nickel 1–5, silicon 0·4–1·25, chromium 0·05–0·5, iron 0·2–0·5, per cent., remainder copper. The alloys are suitable for use in such parts as fasteners (for electrical applications), crankshafts, connecting rods, and springs.

VEREINIGTE DEUTSCHE METALLWERKE A.G.
(inventor, K. DIES). *German Pat.* 1,107,943.

Wear-Resistant Nickel-base Alloys

Readily-castable wear-resistant nickel-base alloys, possessing a high degree of thermal stability, and exhibiting good resistance to shock, corrosion and oxidation, fall within the following limits of composition: chromium 25–30, cobalt 8–12, silicon 0–1·5, manganese 0–2, tungsten 5–12, iron 10–15, carbon 0·8–1·6, molybdenum 5–12, weight per cent., remainder (at least 20 per cent.) nickel.

The use of such alloys for valve seats for internal-combustion engines is specifically claimed.

S. K. ELBAUM and E. L. WAGONER, assignors to UNION CARBIDE CORPORATION. *French Pat.* 1,256,200.

Nickel-containing High-Temperature Bearing Materials

Anti-friction elements, such as bearings for shafts and other moving parts, and, in particular, bearings for use under high-temperature conditions (e.g., at temperatures in excess of 500°C.), consist of a sintered-powder composition, at least the bearing surface of which contains at least 50 (preferably 60) wt. per cent. of nickel oxide and/or cobalt oxide (or nickel and/or cobalt subjected to surface oxidation after sintering). The friction elements may, optionally, contain a ceramic material (e.g., mullite or magnesia), and they may also be produced from a mixture of nickel or cobalt and nickel-oxide or cobalt-oxide powders subjected to surface oxidation after sintering.

Methods of manufacturing bearings in accordance with the invention are described.

MORGAN CRUCIBLE COMPANY, LIMITED (inventor, A. E. S. WHITE).

Brit. Pat. 871,293.
Similar to *French* „ 1,230,518.

Nickel-containing Tungsten-Carbide Coating Material with Improved Corrosion- and Oxidation-Resistance

The patent covers an alloy-coating material containing tungsten carbide 60–80, chromium carbide 14–34, nickel 4–8, wt. per cent. The material can be applied to various basis metals, to produce an abrasion-resistant deposit with, it is stated, resistance to corrosion and oxidation superior to that shown by tungsten-carbide coatings previously available.

A preferred method of preparing the coating material involves mixing a powder comprising tungsten 65·5, 80%chromium-20%nickel alloy 28·5, carbon 6, wt. per cent., sintering and carburizing the mixture in a reducing atmosphere at 1400°F. (760°C.), and finally crushing to powder. The coating is preferably applied by means of a high-velocity high-temperature gas stream from a detonation gun.

J. F. PELTON and J. M. KOFFSKEY, assignors to UNION CARBIDE CORPORATION. *Brit. Pat.* 874,463.

Copper-Nickel Corrosion-Resistant Thermocouple Alloys

The invention arose from the finding that, by adding small amounts of alloying elements to a copper-nickel-base alloy of 60–40 type, it is possible to produce a series of alloys whose thermoelectric power is stable with time and temperature and may be preselected within a wide range, and whose corrosion-resistance is equal to, or greater than, that of commercially available copper-nickel thermocouple alloys. The addition of a single one of these alloying elements is stated to have a predictable influence on thermoelectric power and corrosion-resistance.

The patent covers a copper-nickel alloy thermocouple element, with stable reproducible voltage-temperature characteristics, containing one or more of the following elements entirely in solid solution and within the limits stated, the copper-nickel ratio of the alloy lying in the range 16·5/39·5 to 57·5/42·5: aluminium 0·01–4, antimony 0·01–8, beryllium 0·005–1, chromium 0·001–2, cobalt 0·01–2, indium 0·02–3, iron 0·001–2, magnesium 0·01–2, manganese 0·01–15, molybdenum 0·001–2, niobium 0·001–2, silicon 0·005–4, tantalum 0·01–5, tellurium 0·02–1, tin 0·01–5, titanium 0·005–2, tungsten 0·005–2, vanadium 0·001–1, zirconium 0·02–3, wt. per cent.

LEEDS AND NORTHRUP COMPANY.

Brit. Pat. 872,001.

Thermocouple for Use at 900°–1100°C.

The invention provides a thermocouple particularly suitable for measuring temperature in the range 900°–1100°C. Compared with thermocouples conventionally used in industry for measurements in this temperature range, it has a higher resistance to the corrosive effects of furnace gases (in particular, those containing oxygen and sulphur), and is more resistant in reducing furnace atmospheres to 'green rot'. Its electromotive force is as high in the relevant temperature range as that of known nickel-chromium alloy thermocouples likely to be corroded under the same service conditions.

The thermocouple comprises: (1) an electropositive element which, possessing high resistance to green rot, consists essentially of an alloy containing chromium 9–11, iron 1–3, one or more of the metals magnesium, calcium, strontium and barium 0·1–1, per cent., remainder nickel; and (2) an electronegative element containing iron 0·2–2, manganese 2–4, aluminium 2–4, per cent., remainder nickel. The thermoelectric behaviour of the combination satisfies the standard requirements laid down in *N.B.S. Circular* 561 and/or those stipulated in German specification *DIN* 43710.

W. OBROWSKI and C. VON SEELEN, assignors to DEUTSCHE GOLD- UND SILBER-SCHEIDEANSTALT.

U.S. Pat. 2,990,440.

Cobalt-Nickel-base Turbine-Blading Alloys

The precipitation-hardenable cobalt-nickel-base alloys to which the patent relates possess, at temperatures in the range 1200°–1500°F. (650°–810°C.), good tensile and stress-rupture properties, useful damping capacity, and high resistance to overageing under stress. Their use for the manufacture of precipitation-hardened turbine blades intended for service in this temperature range is specifically claimed.

The alloys contain: nickel 20–24, beryllium 0·3–1·5, zirconium up to 2, molybdenum up to 4 (molybdenum + zirconium 1–6), chromium up to 2·5, per cent., remainder cobalt.

J. T. BROWN, C. P. MUELLER, L. L. FRANCE and A. W. COCHARDT, assignors to WESTINGHOUSE ELECTRIC CORPORATION. *U.S. Pat.* 2,981,620.

Production of Cooling Passages in Nickel-base Turbine Blades

The leaching of a filler from a hole in an alloy article by an acid solution that attacks the filler exclusively or preferentially is accelerated, according to the invention claimed, by the presence, in the hole, of one or more wires which are unattacked by the acid. The wire or wires are believed to prevent the formation of a stable bubble structure (with its inhibitive effect on the reaction) during leaching.

A preferred filler material consists of a rod of material attacked by a nitric-acid leaching solution (e.g., mild steel or an iron-manganese-titanium alloy) and one or more wire cores which are resistant to such attack (e.g., a nickel-base alloy).

The application of the invention to the production of cooling passages in turbine blades extruded from nickel-chromium or nickel-chromium-cobalt creep-resisting alloy billets is specifically claimed.

HENRY WIGGIN AND COMPANY, LIMITED (inventors, C. C. HORNE and G. R. STUART). *Brit. Pat.* 874,953.

See also

In the production of cooling passages in turbine blades fabricated from nickel-chromium and nickel-chromium-cobalt alloys, a suitable material for filling the holes in the billet, before it is extruded to aerofoil shape, is the iron-manganese-titanium alloy described in Brit. Pat. 763,115. To be completely satisfactory, the carbon content of the filler alloy should be less than 0·1 per cent., but, at this carbon content, decarburization has occurred in the billet alloy in the immediate vicinity of the filler. If the billet alloy contains less than 1 per cent. carbon, the decarburization causes local grain-growth around each cooling passage. According to the invention, this undesirable grain-growth is prevented by providing the filler with a carbon-rich surface coating or subjecting it to superficial carburization (preferably by coating the walls of the holes in the billet with carbonaceous material).

The application of the invention to a billet alloy containing chromium 10–21, cobalt 0–22, molybdenum 0–5·5, titanium 1–3, aluminium 0·5–6, silicon up to 1·5, manganese up to 1, per cent., remainder nickel, and to a filler alloy containing manganese 5–20, titanium 1–10, carbon less than 0·1, per cent., remainder iron, is claimed.

HENRY WIGGIN AND COMPANY, LTD. (inventors, R. E. BUTTRESS, B. KEEGAN and G. R. STUART). *Brit. Pat.* 874,954.

Iron-Nickel-base Precipitation-Hardenable Austenitic Alloys

The precipitation-hardenable iron-base alloys covered by the patent are stated to be suitable for use in highly stressed moving parts (e.g., in gas-turbine applications) at temperatures up to 1500°F. (815°C.). They contain a minimum of strategic alloying elements, and exhibit high strength, good ductility and adequate corrosion-resistance at service temperatures.

The alloys, which fall within the following composition range, are subjected to a treatment involving quenching from a solution temperature in the range 2000°–2100°F. (1095°–1150°C.) after solution-treatment for ½–2 hours, ageing at 1500°–1600°F. (815°–870°C.) for 18–30 hours, and then ageing for 12–20 hours at 1350–1450°F. (735°–785°C.): carbon up to 0·15, manganese up to 1·5, silicon up to 1·5, chromium 10–20, nickel 30–35, aluminium + titanium 2·5–5 (aluminium 0·5 min., titanium 1 min.), molybdenum 1–8, tungsten 2–15, vanadium trace up to 1·5, iron 20–48, per cent.

Data exemplifying mechanical properties are included in the specification.

W. W. DYRKACZ, G. AGGEN and E. E. REYNOLDS, assignors to ALLEGHENY LUDLUM STEEL CORPORATION. *Canad. Pat.* 620,380.

Chromium-Nickel-Manganese Heat-Resisting Austenitic Steel

Brit. Pat. 838,294 claimed a chromium-nickel-molybdenum steel particularly suitable for use as superheater tubing at metal temperatures up to about 700°C. The present patent of addition covers an austenitic steel of the following modified composition: carbon 0·05–0·15, chromium 12–18, nickel 6–20, manganese 3–10, boron 0·005–0·075, niobium and/or tantalum 0·5 min., with or without vanadium (niobium + tantalum + vanadium 3 max.), molybdenum 0·5–4, tungsten 0–3·5 (molybdenum + tungsten 4 max.), per cent., remainder iron.

The reduction in boron content from the range 0·005–0·5 per cent., made to improve hot workability and weldability, is associated with a reduction in stress-to-rupture properties, which is, however, offset by the high niobium + tantalum content.

UNITED STEEL COMPANIES, LIMITED (inventor, J. D. MURRAY). *Brit. Pat.* 876,437.

Chromium-Manganese-Nickel Cast Stainless Steel

Corrosion-resisting austenitic cast steels, which 'possess properties that are, in certain respects, substantially equal to, or better than, the stainless steels of the 300 series', fall within the following limits of composition: carbon 0·12 max., silicon 1 max., chromium 18–21, manganese 0–17, nickel 2–8, nitrogen 0·1–0·5, wt. per cent., remainder iron. The amounts of nickel, manganese and nitrogen present are determined in accordance with a diagram included in the specification. To decrease the amounts of undesirable constituents, the casting is heat-treated at a temperature in the range 1950°–2200°F. (1065°–1205°C.) and then quenched.

J. KANTER, A. F. LAHR and K. HAEFNER, assignors to CRANE COMPANY. *Canad. Pat.* 622,504.

Heat-Hardenable Chromium-Nickel Austenitic Steel

The patent covers an austenitic chromium-nickel stainless steel which 'possesses good hot-working properties, which readily lends itself to hardening and strengthening by heat-treatment at temperatures which are not such as to cause objectionable scale formation and heat-tinting, and which, in the hardened condition, is tough and corrosion-resistant'. The following compositional limits are claimed: chromium 12–18, nickel 13–30, silicon 3–6·5, molybdenum 1–4·5 (molybdenum+silicon 5·5 min.), carbon 0·15 max., manganese up to 4, copper up to 3, tungsten up to 3, niobium up to 1, nitrogen up to 0·2, per cent., remainder iron. Heat-treatment involves solution-treatment at 2000°–2300°F. (1095°–1260°C.), cooling, and finally hardening at 1200°–1500°F. (650°–815°C.).

A Rockwell hardness of C 33, an average tensile strength of 154,500 p.s.i. (69 t.s.i.: 108·5 kg./mm.^{2}), and an average 0·2 per cent. yield strength of 84,300 p.s.i. (37·5 t.s.i.: 59·5 kg./mm.^{2}) are, it is stated, obtainable in such steels after hardening treatment.

H. TANCZYN. *U.S. Pat.* 2,984,563.

High-Strength Corrosion-Resistant Cast Steels

Corrosion-resisting cast steels of the following composition are characterized by their ability to be heat-treated (preferably by age-hardening) to high strengths, without, it is stated, adverse effects on corrosion-resistance: carbon 0·01–0·08, manganese 0–2, silicon 0·3–2, chromium 24–28, nickel 3–6·5, copper 2·5–3·5, molybdenum 1·5–2·5, iron 68·69–55·42, per cent.

L. R. BIDWELL, F. H. BECK and M. G. FONTANA, assignors to OHIO STATE UNIVERSITY RESEARCH FOUNDATION.

Canad. Pat. 621,945.

18-16-Mo Stainless Steel Resistant to Corrosion by Nitric Acid

The invention is based on the finding that adequate resistance to corrosion by nitric acid can be conferred on sensitized A.I.S.I. Type 316L stainless steels by limiting the silicon content to 0·6 max. per cent., raising the nickel content to 14·3 per cent. min., and maintaining the chromium content above 17 per cent. (provided that, within such limits, the composition is adjusted to ensure a completely austenitic structure).

Accordingly, the patent covers a molybdenum-containing hot-worked chromium-nickel austenitic steel, which is free from delta ferrite after hot working below 2000°F. (1095°C.), has a penetration rate of less than 0·002 in. (0·05 mm.) per month in boiling 65 per cent. nitric acid after a sensitization treatment of 2 hours at 1250°F. (675°C.) and air cooling, and contains cobalt 0–0·035, manganese 0–2 (preferably 1·5 max.), silicon 0–0·6, nickel 14·3–17 (preferably 16 max.), chromium 17–21 (preferably 18·5 max.), molybdenum 2–3·1, per cent.

UNITED STATES STEEL CORPORATION.
Brit. Pat. 872,052.
Similar to *French* „ 1,184,404.

Copper-Nickel-base Wide-Gap High-Temperature Brazing Alloys

The invention provides copper-nickel-base brazing alloys suitable for use in brazing joints in high-temperature alloys without resulting in intergranular attack or embrittling effects.

The following compositional range is claimed: nickel 30–40, indium 2–10, silicon up to 3, wt. per cent., remainder copper. An alloy powder mixture preferred for wide-gap brazing comprises (1) about 75–95 wt. per cent. of the brazing alloy containing nickel 30–40, indium 2–10, silicon up to 3, wt. per cent., remainder copper, and (2) 5–25 wt. per cent. of a nickel-base brazing alloy containing silicon 1·5–5, boron 0·5–3·5, chromium up to 8, wt. per cent., remainder nickel.

The advantages of the brazing alloys claimed are exemplified in relation to their application to 'René 41'.

G. S. HOPPIN, assignor to GENERAL ELECTRIC COMPANY. *U.S. Pat.* 2,988,447.

Copper-Nickel-Phosphorus Alloy for Brazing Steels

A brazing alloy, with a satisfactorily low brazing temperature, stated to be particularly suitable for use in brazing steels, and to exhibit exceptional strength and resistance to creep at temperatures up to 1500°F. (815°C.), contains copper 70–90, nickel

9-27, phosphorus 1-3, per cent., the amount of phosphorus present being such as to place the melting temperature of the alloy in the range 1950°-2100°F. (1065°-1150°C.). The following preferred composition is claimed: copper 80, nickel 18, phosphorus 2, per cent.

AIR PREHEATER CORPORATION.

Brit. Pat. 875,881.
Similar to *S. African* „ 4770/58.
„ „ *U.S.* „ 2,911,298.
„ „ *Canad.* „ 622,411.

Corrigenda

Nickel Bulletin, 1961, vol. 34, No. 5, p. 118.

Electrodeposition of Nickel-Copper Alloys from the Pyrophosphate Solution, Line 3 of Footnote.

For 'Nos. 2 and 3',
Read 'Nos. 2 and 4'.

Nickel Bulletin, 1961, vol. 34, No. 6, p. 170.

Selection of Materials for Marine Applications: Economic Considerations, Right-hand Column, Paragraph (5).

For '70-30 Cu-Ni-Fe (Commercial) .. 1865 (24 per cent. retubed in 15 years)'
Read '70-30 Cu-Ni-Fe (Commercial) .. 18·5 (24 per cent. retubed in 15 years)'

Nickel Bulletin, 1961, vol. 34, No. 7-8, p. 179.

Brightening and Levelling Characteristics of Organic Addition Agents and their Effects on Stress in Nickel Deposits, Right-hand Column, Lines 9 and 10 of Last Paragraph.

For 'concentrations of 0·2-5 g./L., respectively',
Read 'concentrations of 0·2 and 5 g./L., respectively'.

Nickel Bulletin, 1961, vol. 34, No. 9, pp. 222-3.

Spheroidal-Graphite Iron Castings: British Standard, p. 223, Line 1 of Last Paragraph.

For 'Grade SNG 27/2',
Read 'Grade SNG 27/12'.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Trade Marks*.